WATER HEATING

DOMESTIC HOT WATER LOOP TEMPERATURE CONTROLLER, MULTIFAMILY

SWWH016-01

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MEASURE NAME

Domestic hot water loop temperature controller

STATEWIDE MEASURE ID

SWWH016-01

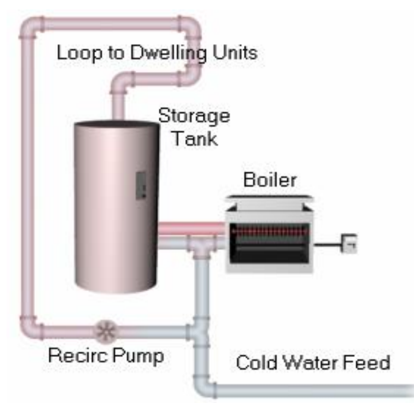
TECHNOLOGY SUMMARY

The domestic hot water (DHW) boiler reset controller is a retrofit measure that will reduce circulating hot water temperature and associated piping and distribution system losses, which will result in energy savings.

It is common to operate several separate DHW loops to supply domestic hot water to the guest/tenant rooms at a moderately high temperature (~120 °F or higher). The figure depicts a typical DHW water system. An ON/OFF boiler will turn ON when the water temperature in the storage tank drops below its lower-limit setting. The recirculation pump will typically operate continuously to maintain the hot water loop temperatures.

Most multifamily facilities have constant-temperature controllers that maintain the water temperature in the storage tank. The upper setpoint is typically 140 °F, even though the specified temperature of the hot water delivered to the units/guest rooms might be 120 °F or lower. Water consumption for personal use requires temperatures at the faucet to be between 100 °F and 110 °F.[1] (The ASHRAE Handbook for HVAC applications recommends 105 °F for hand washing and 110 °F for showers and tubs.) Depending on the time of day and DHW consumption rate, energy consumption for the standby losses may be greater than the energy consumption for the actual hot water use.

Typical Domestic Hot Water System for Multifamily or Lodging Facility



The DHW boiler reset controller measure is a programmable set-back temperature controller on the DHW system. A programmable set-back controller saves energy by lowering the DHW thermostat setting during times of low DHW usage. The DHW system will still provide the minimum required hot water temperature to the rooms, but with significant energy savings. The DHW controller reduces the heat loss from the tank and pipes and reduces the temperature of the hot water delivered to the dwelling units by minimizing the water temperature in the storage tank. Using the DHW controller, the storage tank temperature is highest during times of maximum hot water use by the tenants (mornings), and lowest in the middle of the night.

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[1] American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE). 2015. *2015 ASHRAE Handbook – HVAC Applications.* Atlanta (GA): ASHRAE. Page 49.10, Table 3.

MEASURE CASE DESCRIPTION

This measure case is defined as the addition of a new “temperature modulation” boiler controller in the central water heating system of qualifying multifamily facilities to minimize the supply and return water temperatures and piping heat losses. The temperature modulation protocol is based on a real-time data stream or historical trending based on measured hot water draw patterns.

Some multifamily facilities may require more than one boiler controller. The total gas savings are based on the number of multifamily dwelling units controlled by the new boiler controller(s). In particular, measure offerings (and thus savings) are provided in increments of five dwelling units, as shown below.

Measure Case Specification by Number of Dwelling Units

Number of Dwelling Units of Treated Property	Measure Offering & Number of Dwelling Units for UES Calculation
1-5 units	DHW Loop Controller, Multifamily, 5 Units, Gas
6-10 units	DHW Loop Controller, Multifamily, 10 Units, Gas
11-15 units	DHW Loop Controller, Multifamily, 15 Units, Gas
16-20 units	DHW Loop Controller, Multifamily, 20 Units, Gas
21-25 units	DHW Loop Controller, Multifamily, 25 Units, Gas
26-30 units	DHW Loop Controller, Multifamily, 30 Units, Gas
31-35 units	DHW Loop Controller, Multifamily, 35 Units, Gas
36-40 units	DHW Loop Controller, Multifamily, 40 Units, Gas
41-45 units	DHW Loop Controller, Multifamily, 45 Units, Gas
46-50 units (or > 50)	DHW Loop Controller, Multifamily, 50 Units, Gas

BASE CASE DESCRIPTION

The base case is defined as the existing water heating system of qualifying multifamily facilities without “temperature modulation” boiler control. The baseline domestic hot water (DHW) system typically maintains a continuous supply temperature of 135 °F or higher. This is sufficient to meet the demand requirements at design conditions, but this temperature is excessive otherwise and will result in high distribution system losses.

CODE REQUIREMENTS

There are no state or federal code requirements that govern this measure.

Applicable State and Federal Codes and Standards

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20 (2014)	None.	n/a
CA Building Energy Efficiency Standards – Title 24 (2013)	None.	n/a
Federal Standards	None.	n/a

NORMALIZING UNIT

Household (number of dwelling units).

PROGRAM REQUIREMENTS

Measure Implementation Eligibility

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
Add-on equipment	DnDeemed	Res

Eligible Products

This measure qualifies only for hot-water systems used primarily for domestic hot-water heating.

Eligible Building Types

This measure is applicable for qualifying multifamily facilities with a central water heating system.

Eligible Climate Zones

The measure is applicable in all California climate zones.

PROGRAM EXCLUSIONS

No other building types or applications are eligible.

DATA COLLECTION REQUIREMENTS

Data collection requirements are to be determined.

USE CATEGORY

Service & domestic hot water

ELECTRIC SAVINGS (kWh)

Not applicable.

PEAK ELECTRIC DEMAND REDUCTION (kW)

Not applicable.

GAS SAVINGS (Therms)

The annual gas unit energy savings (UES) due to the installation of temperature modulation control on a centralized domestic hot water (CDHW) system of a multifamily building was derived from baseline and measure case DOE-2 energy use simulation models (via eQuest® 3-64).[2] The baseline and measure case energy use consumption (UEC) models are described below.

Baseline Energy Use Simulation

The initial step was to establish a simulation with as many similarities to the DEER database simulations as possible. This was done by referencing the DEER multifamily prototypes published in 2005[3] and the initial eQuest default values, as noted below.

eQuest Default Occupancy, Lighting, Ventilation, Miscellaneous Load Schedules. The eQuest schedules were chosen instead of the DEER 2005 schedules because the values found in 2005 analysis were relatively extreme and non-continuous compared to the newer schedules within the eQuest software.

Design Domestic Hot Water Flow (GPM) is equal to approximately 1.9 gpm. Design gpm was drawn directly from eQuest; the derivation of this metric is represented below.

$$Design\ GPM = \frac{(Daily\ Gal./Person) \times (Number\ of\ People)}{(Number\ of\ Active\ Hours/Day) \times (60\ Minutes/Hr)}$$

Design DHW Flow Inputs

Parameter	Value	Source
Daily Usage (gal/person/day)	20	eQuest 3-64
Number of People	36	
Number of Active Hours/Day	6.329	

[2] Southern California Gas Company. 2014. "DWHT Reset Controller Summary.xls."

Southern California Gas Company. 2014. "DHWT Reset Controller Simulation 1.1.zip"

[3] California Public Utilities Commission (CPUC), Energy Division, Ex Ante Review Team. 2005. "DEER Multi Family Split AC Gas Furn.xlsx"

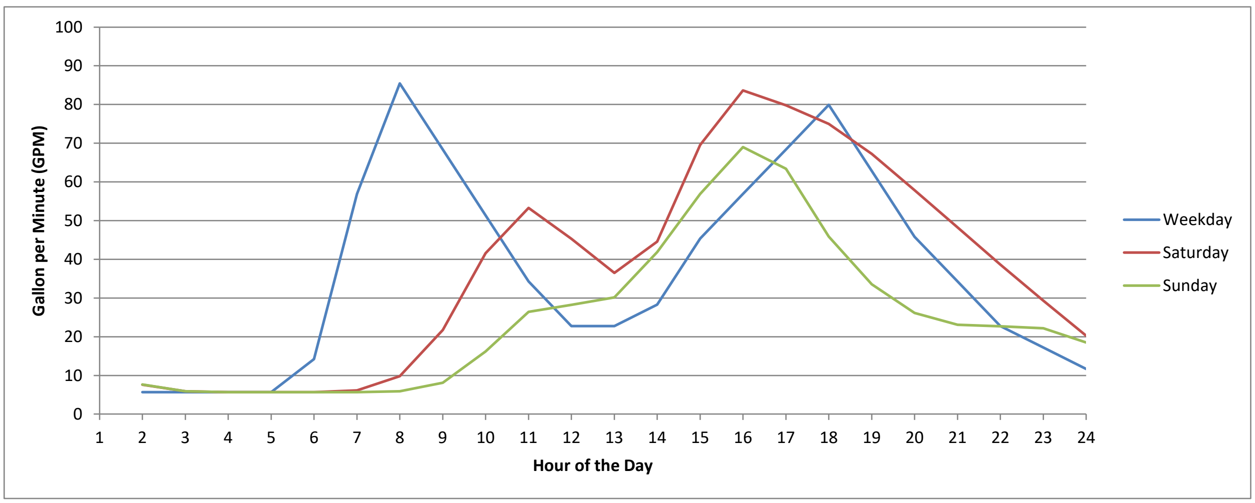
The following modifications ensured that the measure was being applied to realistic conditions:

- The domestic hot water loop within the DEER multifamily prototype model was altered to have 50% recirculation. This value was referenced within the DEER DHW prototype (see "Motels" tab).[4]
- The (conservative) estimated of the total heat loss through the piping is equal to 5 °F.

Heating Schedule was altered to quantify the energy savings, which is a constant temperature of 135 °F for the baseline.

Load Shapes. To account for the unique domestic hot water usage in multifamily dwelling units, the default schedules shown below were used in the eQuest simulation. These schedules were developed in two parts by the software developers of eQuest. The first portion is the design criteria where the maximum daily average consumption is calculated. The second portion is the fractional profile that provides the variability throughout the day. The product of these two variables is represented in the figure below.

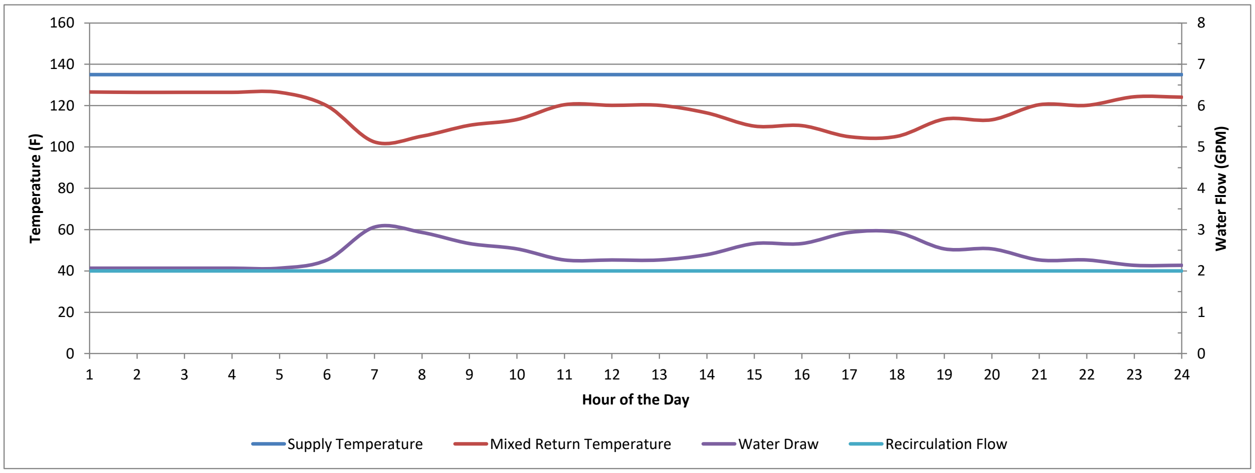
DHW Demand for Weekdays, Saturdays, and Sundays for Multifamily Buildings



The following figures depict the daily operating conditions for both control strategies. The "Operating Conditions of the Baseline Controls System" figure presents the hot water supply temperature (constant 135 °F), mixed water temperature (from the addition of makeup cold water to the return hot water in the recirculating loop), the hot water draw schedule (gpm), and the hot water recirculation flow (gpm).

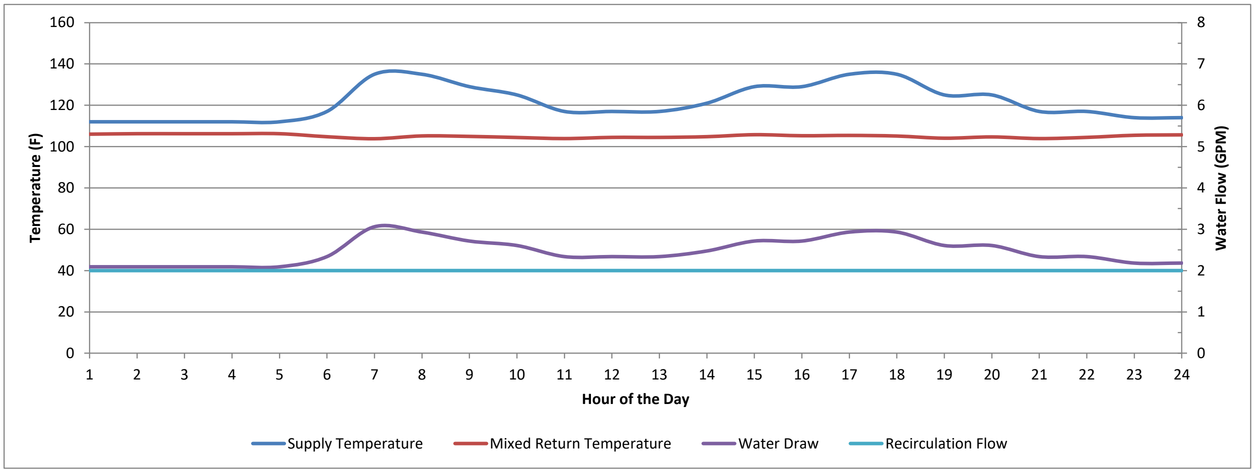
[4] California Public Utilities Commission (CPUC), Energy Division, Ex Ante Review Team. 2005 "DEER DHW Prototype Characteristics." "DHW Properties-050714b.xlsx." Revised June 1.

Operating Conditions of the Baseline Controls System



As shown below, temperature modulation control was assumed to reduce the supply temperature by 22 °F (135 °F to 113 °F) from 1 a.m. to 5 a.m. in the morning and reaching maximum setpoint temperature of 135 °F during peak hot water demand at 8 a.m. and 5 p.m. before it drops again during the night hours. A continuous monitoring system monitors different operation parameters of the DHW system and automatically provides system operation status and malfunction updates to system operators.

Operating Conditions of CDHW Temperature Modulation and Monitoring Controller



All other load shapes associated with this analysis (Occupancy Fraction Profile, Lighting Fraction Profile, Task Lighting Fraction Profile, Miscellaneous Load Fraction Profile, etc.) were defaulted within the eQuest simulation software and can be referenced within the simulation files directly.[5]

[5] Southern California Gas Company. 2014. "DHWT Reset Controller Simulation 1.1.zip"

Baseline Model Calibration

The comparison of the baseline simulation with the 2009 Residential Appliance Saturation Survey (RASS) study results is provided below.[6] Considering the statistical variance of the data collected by the RASS Study, the estimated error of 18% is reasonable.

Comparison between the RASS Study and the Baseline of eQuest Simulation

Source	UEC (Therm/dwelling unit)	Source
2009 RASS Study	183	KEMA, Inc. 2010. *2009 California Residential Appliance Saturation Survey. Volume 2: Results.* Prepared for the California Energy Commission. CC-200-2010-004.
Baseline of eQuest Simulation	216	Southern California Gas Company. 2014. "DWHT Reset Controller Summary.xls."
% Error	18%	-

Measure Case Energy Use Simulation

With a calibrated simulation, the demand-based hot water temperature schedules were input into the simulation to emulate a demand-based temperature controller. The schedule was developed by referencing the eQuest default fractional load profiles on the domestic hot water circulation loops. It was assumed that a load factor of just above 0% would have a setpoint of 110 °F and a load factor of 67% would have a setpoint of 135 °F. Any load factor between the two reference points was interpolated.

Logic of the Simulated Demand Based Control Strategy

Load Factor	Setpoint (°F)
0%	110 °F
0% - 67%	Interpolated
67%+	135 °F

The table below provides demand-based curves for the simulation used in this analysis. With this control strategy the recirculation loop will require less heating in low usage periods due to the lower setpoint.

Proposed Temperature Modulation and Continuous Monitoring Controller Schedule

Hour	Temperature Schedules (°F)		
	Weekday	Saturday	Sunday
1	112	113	113
2	112	112	112
3	112	112	112
4	112	112	112

[6] KEMA, Inc. 2010. *2009 California Residential Appliance Saturation Survey. Volume 2: Results.* Prepared for the California Energy Commission. CC-200-2010-004. See Table 2-21.

Hour	Temperature Schedules (°F)		
	Weekday	Saturday	Sunday
5	112	112	112
6	117	112	112
7	135	112	112
8	135	114	112
9	129	120	113
10	125	127	117
11	117	128	120
12	117	122	118
13	117	122	121
14	121	127	126
15	129	135	131
16	129	135	134
17	135	135	128
18	135	134	123
19	125	131	119
20	125	127	118
21	117	124	117
22	117	121	117
23	114	118	117
24	114	115	15

Unit Energy Savings

The simulation baseline and measure case UEC results and calculated annual UES per multifamily building and per dwelling unit are presented below. The therms per dwelling unit was then multiplied by the number of dwelling units for the UES calculation as noted in the table below.

Simulation Results

	Baseline	Measure Case
Annual UEC (therms/yr)	3,664.00	3,443.00
Annual UES (therms/yr)	-	222.00
Annual UES (therms/yr/dwelling unit)	-	18.46

Measure Case Specification by Number of Dwelling Units

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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. EUL is often, but not always, derived from measure persistence or retention studies. 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 RUL is only applicable to the first baseline period for a retrofit measure with an applicable code baseline.

As per Resolution E-4807, the California Public Utilities Commission (CPUC) defined the EUL of add-on equipment as the minimum of the EUL of the measure itself and the RUL of the host equipment.[7] 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." This approach provides a reasonable RUL estimate without the requiring any prior knowledge about the age of the equipment being replaced.[8]

The EUL and RUL specified for this boiler reset controller measure are specified below. The host equipment is a large gas water heater in a multifamily central hot water distribution system. The Database for Energy Efficient Resources (DEER) 2014 specified the estimated life for two measures relevant for this host equipment; a residential gas water heater with the EUL of 11 years (*WtrHt-Res-Gas*) and a commercial water heater with an EUL of 15 years (*WtrHt-Com*). The residential gas water heater EUL is suitable for small water heater used in residential homes. Large water heaters in multifamily central hot water system are typically built in commercial grade. Instead of specifying the commercial water heater lifetime, an estimated lifetime of 15 years is proposed, which is equivalent to the commercial water heater but specific to multifamily central hot water system equipment.

Effective Useful Life and Remaining Useful Life

Parameter	Years	Source
EUL – Boiler controls for hot water	15.0	California Public Utilities Commission (CPUC). 2014. "DEER2014-EUL-table-update_2014-02-05.xlsx."
EUL – Host gas water heater	15.0	California Public Utilities Commission (CPUC), Energy Division. 2003. Energy Efficiency Policy Manual v 2.0. Page 17.
RUL – Host gas water heater	5.0	California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 32.

[7] California Public Utilities Commission (CPUC). 2016. *Resolution E-4807*. December 16. Page 13.

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

BASE CASE MATERIAL COST ($/UNIT)

Insofar as the boiler reset controller measure is installed only as add-on equipment, the base case assumes that the existing boiler is not equipped with a modulating controller, thus, the base case material cost is $0.

MEASURE CASE MATERIAL COST ($/UNIT)

The measure case material cost was derived from third-party energy efficiency programs administered by the Southern California Gas Company in the 2007-2008 program cycle.[9] This average cost per installation was then divided by the number of dwelling units (in increments of five units up to 50 units) to derive the measure case material cost per multifamily dwelling unit.

BASE CASE LABOR COST ($/UNIT)

Insofar as the boiler reset controller measure is installed only as add-on equipment, the base case assumes that the existing boiler is not equipped with a controller, thus, the base case labor cost is $0.

MEASURE CASE LABOR COST ($/UNIT)

The installation labor cost is included in the reported measure case cost (see Measure Case Material Cost).

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 NTG value is based upon the average of all NTG ratios for all evaluated 2006 – 2008 residential programs, as documented in the 2011 DEER Update Study conducted by Itron, Inc.[10] This sector average NTG ("default NTG") is applicable to all energy efficiency measures that have been offered through residential sector programs for more than two years and for which impact evaluation results are not available.

Net-to-Gross Ratios

Parameter	Value	Source
NTG – Residential	0.55	Itron, Inc. 2011. *DEER Database 2011 Update Documentation.* Prepared for the California Public Utilities Commission. Page 15-4 Table 15-3.

[9] Southern California Gas Company (SCG). 2008. *DHW Commissioning and Control System for Lodging Facilities Workpaper for PY2007-2008.* Prepared by Energy and Environmental Analysis, Inc.

[10] 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 Rates

Parameter	Value	Source
GSIA	1.0	California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 31.

NON-ENERGY IMPACTS

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

DEER DIFFERENCES ANALYSIS

This section provides a summary of DEER-based inputs and methods, and the rationale for inputs and methods that are not DEER-based.

DEER Difference Summary

DEER Item	Comment / Used for Workpaper
Modified DEER methodology	DEER2005 Multifamily prototype was referenced
Scaled DEER measure	No
DEER Base Case	No
DEER Measure Case	No
DEER Building Types	No
DEER Operating Hours	
DEER eQUEST Prototypes	DEER prototype was modified
DEER Version	
Reason for Deviation from DEER	Central hot water loop and more recent hot water load schedule.
DEER Measure IDs Used	
NTG	Source: DEER2014. NTG of 0.55 is associate with NTG ID: Res-Default>2yrs
GSIA	GSIA ID: *Def-GSIA*
EUL/RUL	Source: ExAnte2013, READI V2.5.1. The EUL of 15 years is associated with EUL ID: *SHW-EMS.* Source: The RUL is based upon EUL ID: *WtrHt-MF-Gas(proposed).* This Newly proposed EUL_ID with 15 years of life for a commercial-grade large water heater used in multifamily central water heating system: Sector: Res BldgType: MFm BldgLoc: Any EUL_Yrs: 15 RUL_Yrs 5

DEER Item	Comment / Used for Workpaper
	Version: ExAnte2020 VersionSource: PA workpaper

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Revision Complete Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision Effective Date and Approved By
01	03/31/2018	Jennifer Holmes Cal TF Staff	Draft of consolidated text for this statewide measure is based upon: SCGWP100315A, Revision 1 (May 22, 2014) PGECODHW115, Revision 4 (April 1, 2017) Consensus reached among Cal TF members.
	02/27/2019	Jennifer Holmes Cal TF Staff	Revisions for submission of version 01