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APPLIANCE OR PLUG LOAD
CLOTHES WASHER, RESIDENTIAL & MULTIFAMILY

CONTENTS

MEASURE NAME

Clothes Washer, Residential & Multifamily

STATEWIDE MEASURE ID

SWAP004-02

TECHNOLOGY SUMMARY

This measure pertains to ENERGY STAR-certified clothes washers in residential buildings. A significant amount of the energy used for clothes washing is used for heating the water. Horizontal-axis (front loading) clothes washers tumble clothes through a smaller pool of water than conventional vertical-axis (top loading) models, saving up to 50% of energy consumed in the washing process. High-efficiency machines also have more efficient motors that spin clothes two to three times faster than the conventional machines. Thus, more water is removed from the clothes, which reduces the energy required to dry them.

ENERGY STAR clothes washer measure terms:

- The **capacity** is the entire volume measured in cubic feet which a dry-clothes load could occupy within the clothes container during washer operation.
- The **energy consumption per cycle** is equal to the sum of the washing machine electrical energy consumption, the hot water heater energy consumption, and the dryer energy consumption.
- The **integrated modified energy factor (IMEF)** and **modified energy factor (MEF)** indicate how many cubic feet of laundry can be washed and dried with one (1) kWh of electricity. The higher the number, the greater the efficiency. The efficiency requirements for residential clothes washer models are based upon IMEF.
- The **integrated water factor (IWF)** is the number of gallons needed for each cubic foot of capacity. A lower number indicates lower water consumption and therefore represents more efficient use of the water.

MEASURE CASE DESCRIPTION

This measure is defined as a clothes washer that meets the minimum criteria of ENERGY STAR Version 8.0 or the ENERGY STAR Most Efficient 2018.[1] The following table provides the minimum integrated modified energy factor (IMEF) / modified energy factor (MEF) and the maximum integrated water factor (IWF) for the measure offerings defined for this measure. Savings were calculated for each applicable building type and for each investor-owned utility service area for each measure offering.

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[1] ENERGY STAR. 2018. "ENERGY STAR® Program Requirements Product Specification for Clothes Washers - Eligibility Criteria Version 8.0." Effective February 5, 2018.

ENERGY STAR. 2018. "ENERGY STAR Most Efficient Recognition Criteria: Clothes Washers." Effective January 2018.

Measure Case Specification

Tier	Measure Offering	Applicable Building Types	Min. Integrated Modified Energy Factor (IMEF)	Min. Modified Energy Factor (MEF J2)	Max. Integrated Water Factor (IWF)
ENERGY STAR Residential	Top-Loading > 2.5 cubic feet	Single family Mobile home Multifamily (in unit) Multifamily (common)	2.06	n/a	4.3
	Front-Loading > 2.5 cubic feet		2.76	n/a	3.2
ENERGY STAR Commercial	Front Loading Purchased	Multifamily (common)	n/a	2.20	4.0
	Front Loading Leased				
ENERGY STAR Most Efficient Residential	Top-Loading > 2.5 cubic feet	Single family Mobile home Multifamily (in unit) Multifamily (common)	2.92	n/a	3.2
	Front-Loading > 2.5 cubic feet				

Measure Case Offering IDs

Tier	Measure Offering	Statewide Measure Offering ID	Energy Impact ID	DEER Version
ENERGY STAR – Residential	Top-Loading > 2.5 ft^3	SWAP004G (Dwelling)	Appl-CW-Top-Tier1	DEER 2020
		SWAP004H (Common)	Appl-CW-Top-Tier1 (Scaled)	
	Front-Loading > 2.5 ft^3	SWAP004A (Dwelling)	Appl-CW-Front-Tier2	DEER 2020
		SWAP004B (Common)	Appl-EW-Front-Tier2 (Scaled)	
ENERGY STAR Most Efficient (ESME) – Residential	Top-Loading > 2.5 ft^3	SWAP004I (Dwelling)	Appl-CW-Top-Tier3 (Scaled)	DEER 2020
		SWAP004J (Common)	Appl-CW-Top-Tier3 (Scaled)	
	Front-Loading > 2.5 ft^3	SWAP004C (Dwelling)	Appl-CW-Front-Tier3	DEER 2020
		SWAP004D (Common)	Appl-CW-Front-Tier3 (Scaled)	
ENERGY STAR – Commercial	Front Loading, Owned	SWAP004E	n/a	n/a
	Front Loading, Leased	SWAP004F	n/a	n/a

BASE CASE DESCRIPTION

The base case technology for this measure is a top-loading or front-loading residential or commercial clothes washer respective to the measure case that meets the federal and Title 20 California Appliance Efficiency Regulations (see Code Requirements).

Base Case Specification

Tier	Measure Offering	Base Case	Min. Integrated Modified Energy Factor (IMEF)	Min. Modified Energy Factor (MEF J2)	Max. Integrated Water Factor (IWF)
Residential Clothes Washer	Top Loading	Standard Top Loading Clothes Washer	1.29	N/A	8.4

	Front Loading	Standard Front Loading Clothes Washer	1.84	N/A	4.7
Commercial Clothes Washer	Top Loading	Commercial Top Loading Clothes Washer	N/A	1.35	8.8
	Front Loading	Commercial Front Loading Clothes Washer	N/A	2.00	4.1

CODE REQUIREMENTS

Applicable state and federal codes and standards for clothes washers are denoted and further explained below.

Applicable State and Federal Codes and Standards

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20 (2019)	Section 1605.1, Table P-1: Standards for Residential Clothes Washers & Table P-2: Standards for Commercial Clothes Washers	January 1, 2018
Federal Standards	Code of Federal Regulations, 10 CFR 430.32(g)(3)	March 7, 2015
	Code of Federal Regulations, 10 CFR 431.156	January 1, 2018
CA Building Energy Efficiency Standards – Title 24	None.	n/a

California Appliance Efficiency Regulations (Title 20). The 2019 California Appliance Efficiency Regulations (Title 20)[2] requires that all residential clothes washers manufactured on or after the effective dates meet the minimum efficiency requirements for the integrated modified energy factor (IMEF) and the integrated water factor (IWF). Title 20 minimum standards for residential clothes washers follow U.S. Department of Energy (DOE) federal minimum efficiency requirements.

DOE Federal Standards. Clothes washers fall under federal DOE Energy Regulations shown in the following tables.[3] Note that federal standards match the requirements cited in Title 20.

Federal and State Minimum Efficiency Requirements for ENERGY STAR Clothes Washers – Residential

Residential Clothes Washers	Clothes Container Compartment Capacity (ft^3)	Min. Integrated Modified Energy Factor (IMEF)	Max. Integrated Water Factor (IWF)
Compact Top-Loading Clothes Washers	< 1.6 ft^3	1.15	12.0

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[2] California Energy Commission (CEC). 2019. *California Code of Regulations Title 20 Public Utilities and Energy.* CEC-140-2019-002. Revised December 2019.

[3] Code of Federal Regulations at 10 CFR 430.32 (g)(3).

Code of Federal Regulations at 10 CFR 431, Subpart I.

Standard Top-Loading Clothes Washers	≥ 1.6 ft^3	1.57	6.5
Compact Front-Loading Clothes Washers	< 1.6 ft^3	1.13	8.3
Standard Front-loading Clothes Washers	≥ 1.6 ft^3	1.84	4.7

Federal and State Minimum Efficiency Requirements for ENERGY STAR Clothes Washers – Commercial

Residential Clothes Washers	Clothes Container Compartment Capacity (ft^3)	Min. Modified Energy Factor (MEF)	Max. Integrated Water Factor (IWF)
Top-Loading Clothes Washers	Any	1.35	8.8
Front-Loading Clothes Washers	Any	2.00	4.1

NORMALIZING UNIT

Each

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
New construction	UpDeemed	Res
New construction	DnDeemed	Res
New construction	DnDeemDI	Res
Normal replacement	UpDeemed	Res
Normal replacement	DnDeemed	Res
Normal replacement	DnDeemDI	Res

Eligible Products

This measure is defined as a clothes washer that meets minimum criteria of ENERGY STAR Version 8.0 or the ENERGY STAR Most Efficient 2018.[4] Eligible product information for each measure offering is described below.

Energy Efficiency Requirements for Clothes Washers

Measure Offering	Requirements
ENERGY STAR Residential Clothes Washer > 2.5 cubic feet	— Must be an ENERGY STAR-qualified top-loading or front-loading model. — The clothes container volume must be > 2.5 and ≤ 6.0 cubic feet. — Top-loading models must have an Integrated Modified Energy Factor (IMEF) ≥ 2.06 and an Integrated Water Factor (IWF) ≤ 4.3. — Front-loading models must have IMEF ≥ 2.76 and an IWF ≤ 3.2. — Qualified machines that satisfy the ENERGY STAR Connected criteria are allowed an IMEF 5% lower than the minimum qualifying standard.
ENERGY STAR Most Efficient Clothes Washer > 2.5 cubic feet	— Must be an ENERGY STAR Most Efficient model that is a top-loading or front-loading residential model. — The clothes container volume must be > 2.5 and ≤ 6.0 cubic feet. — Models > 2.5 cubic feet must have an IMEF ≥ 2.92 and an IWF ≤ 3.2.
ENERGY STAR Commercial Clothes Washer	— Must be an ENERGY STAR-qualified commercial front-loading model. — The clothes container volume must be > 1.6 and < 8.0 cubic feet. — All models must have MEF J2 ≥ 2.2 and IWF ≤ 4.0
ENERGY STAR Commercial Clothes Washer – Leased	— Must be an ENERGY STAR-qualified commercial front-loading model. — The clothes container volume must be > 1.6 and < 8.0 cubic feet. — All models must have MEF J2 ≥ 2.2 and IWF ≤ 4.0 — Lease Term must be for a minimum term of 5 years and term cannot end prior to five years after the qualified measure is installed. Annual renewal leases do not qualify.

Eligible Building Types

Eligible building types include residential single-family, double-wide mobile homes, and in-unit multifamily residences as well as multifamily common area laundry.

Eligible Climate Zones

The measure is applicable in all California climate zones.

PROGRAM EXCLUSIONS

The following products are not eligible:

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[4] ENERGY STAR. 2018. "ENERGY STAR® Program Requirements Product Specification for Clothes Washers - Eligibility Criteria Version 8.0." Effective February 5, 2018. Page 3.

ENERGY STAR. 2018. "ENERGY STAR Most Efficient Recognition Criteria: Clothes Washers." Effective January 2018.

- Configurations other than a front-loading or top-loading design.
- Residential clothes washer with capacity ≤ 2.5 cubic feet.
- Combination washer-dryers and residential clothes washers with a heated drying functionality.
- Commercial clothes washers < 1.6 or > 8.0 cubic feet

DATA COLLECTION REQUIREMENTS

Data to be collected will include manufacturer and model numbers of measure case washers. Invoice amount will be required to be collected.

USE CATEGORY

Appliance or Plug Load

ELECTRIC SAVINGS (kWh)

The methodology to derive unit energy savings (UES) of an ENERGY STAR clothes washer is dependent upon the product tier/measure offering. The UES of residential clothes washers were drawn from the Database of Energy Efficient Resources (DEER) were calculated as a function of the energy requirements of the washing machine itself, and the energy requirements of the water heater and clothes dryer.

Measure Case Offering and Energy Impact IDs

Tier	Measure Offering	Statewide Measure Offering ID	Energy Impact ID	DEER Version
ENERGY STAR – Residential	Top-Loading > 2.5 ft^3	SWAP004G (Dwelling)	Appl-CW-Top-Tier1	DEER 2020
		SWAP004H (Common)	Appl-CW-Top-Tier1 (Scaled)	
	Front-Loading > 2.5 ft^3	SWAP004A (Dwelling)	Appl-CW-Front-Tier2	DEER 2020
		SWAP004B (Common)	Appl-EW-Front-Tier2 (Scaled)	
ENERGY STAR Most Efficient (ESME) – Residential	Top-Loading > 2.5 ft^3	SWAP004I (Dwelling)	Appl-CW-Top-Tier3 (Scaled)	DEER 2020
		SWAP004J (Common)	Appl-CW-Top-Tier3 (Scaled)	
	Front-Loading > 2.5 ft^3	SWAP004C (Dwelling)	Appl-CW-Front-Tier3	DEER 2020
		SWAP004D (Common)	Appl-CW-Front-Tier3 (Scaled)	
ENERGY STAR – Commercial	Front Loading, Dwelling	SWAP004E	n/a	n/a
	Front Loading, Leased	SWAP004F	n/a	n/a

Residential Clothes Washers – DEER-Based Unit Energy Savings

The measure offerings for which the values were drawn directly from DEER 2020 are specified below. The DEER Measure IDs in this table are only applicable to residential clothes washers installed in single-family, double-wide mobile home, and in-unit multifamily residences.

Clothes Washer DEER Measure IDs

Tier	Measure Offering	DEER Measure ID	Min. Integrated Modified Energy Factor (IMEF)	Max. Integrated Water Factor (IWF)
ENERGY STAR – Residential	ENERGY STAR Top-Loading > 2.5 ft³	RB-Appl-EffCW-med-Tier1-Top	2.06	4.3
	ENERGY STAR Front-Loading > 2.5 ft³	RB-Appl-EffCW-med-Tier2-Front	2.76	3.2
ENERGY STAR Most Efficient (ESME) – Residential	Top-Loading > 2.5 ft³	Scaled from RB-Appl-EffCW-med-Tier3-Front	2.92	3.2
	Front-Loading > 2.5 ft³	RB-Appl-EffCW-med-Tier3-Front		

The UES for ENERGY STAR Most Efficient top-loading clothes washer (2.92 IMEF) is scaled from the top-loading "Tier 3" measure in DEER (2.76 IMEF).

$$UES_{2.92\ IMEF} = UES_{2.76\ IMEF} \frac{\left(\frac{1}{IMEF_{base}} - \frac{1}{2.92}\right)}{\left(\frac{1}{IMEF_{base}} - \frac{1}{2.76}\right)}$$

The UES of a residential ENERGY STAR clothes washer installed in multifamily common area is based upon the DEER savings values corresponding to the DEER Measure IDs in the previous table. However, the savings are scaled proportionally to reflect the increase in wash cycles per year in a multifamily common area compared to residential use. The scaling factors shown below are derived from the number of wash cycles per year specified in the U.S. Department of Energy (DOE) Technical Support Documents (TSDs) for residential clothes washers.

Scaling Factors for Unit Energy Savings of Residential Clothes Washer

Building Type	Wash Cycles per Year	Scaling Factor	Source for Cycles per Year
Single Family	295	-	U.S. Department of Energy (DOE). 2012. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Clothes Washers.* Prepared by Navigant Consulting, Inc. and Ernest Orlando Lawrence Berkeley National Laboratory. Chapter 7, page 7-6.
Multifamily	1,095	3.71	U.S. Department of Energy (DOE). 2014. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Clothes Washers.* Prepared by Navigant Consulting, Inc. and Lawrence Berkeley National Laboratory. Chapter 7, page 7-6.

Commercial Clothes Washers – Non-DEER Unit Energy Savings

Clothes washers for which UES values are not available in DEER include all commercial models. The methodology for calculating the UES and an explanation of the parameters in the calculation are provided below.

Non-Deer Based Commercial Clothes Washers

Tier	Measure Offering	Min. Modified Energy Factor (MEF J2)	Max. Integrated Water Factor (IWF)
ENERGY STAR Commercial	ENERGY STAR Commercial Clothes Washer	2.20	4.0
	ENERGY STAR Commercial Clothes Washer – Leased		

Fundamentally, the UES is equal to the difference between the base case and the measure case unit energy consumption (UEC). The UEC difference is then multiplied by an interactive effects multiplier to account for the change in energy use by the HVAC system due to a change space heating/cooling need.

$$UES_{elec} = [UEC_{elec\ base} - UEC_{elec\ measure}] \times IE$$

The UEC calculation (baseline or measure case) is a function of the energy requirements of the washing machine itself, and the energy requirements of the water heater and clothes dryer; and further assumes that those end uses are electrically powered. These parameters reflect the breakdown of the per-wash cycle energy use by end use. In other words, the electric energy savings for commercial clothes washers must be parsed out into these distinct end uses that are affected by the efficient clothes washer. Further, to acknowledge that the saturation of electric water heating and electric dryers is not 100%, the UEC calculation includes the saturation of electric water heating and electric dryers in the market.

$$UEC_{elec} = CAP \left(\frac{1}{MEF\ J2}\right) \times N \times [pctCW + (pctDHW \times pctDWH_{elec}) + (pctDryer \times pctDryer_{elec})]$$

$CAP =$	Capacity of clothes washer (ft^3)
$MEF\ J2 =$	MEF of clothes washer, base or measure case (ft^3/kWh-wash cycle)
$N =$	Number of wash cycles per year
$pctCW =$	Portion of energy usage attributable to clothes washer, base or measure case (%)
$pctDHW =$	Portion of energy usage attributable to hot water heater, base or measure case (%)
$pctDryer =$	Portion of energy usage attributable to clothes dryer (%)
$pctDHW_{elec} =$	Saturation of electric water heating (%)
$pctDryer_{elec} =$	Saturation of electric dryers (%)

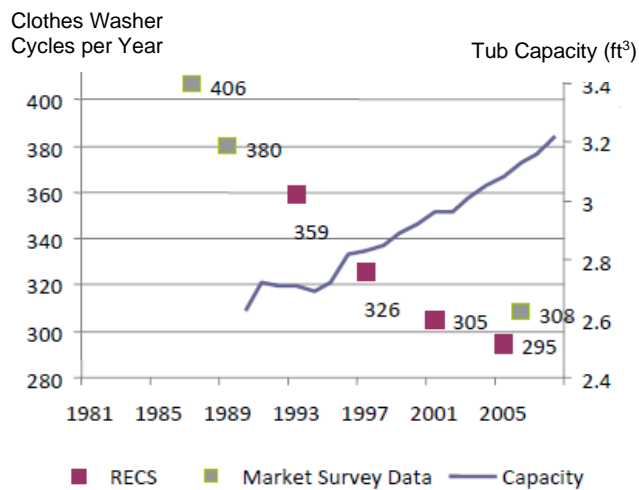The inputs parameters are specified and explained below.

UEC Inputs

Parameter	Base Case Model	Measure Case Model	Source
Clothes washer capacity (ft^3)	3.1	3.1	Assumption to normalize UEC and UES

Parameter	Base Case Model	Measure Case Model	Source
Market Percent – Top Loading	70%	0%	*Base case:* U.S. Department of Energy (DOE). 2014. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Clothes Washers.* Prepared by Navigant Consulting, Inc. and Lawrence Berkeley National Laboratory. Chapter 9. *Measure case:* ENERGY STAR. 2020. "ENERGY STAR Certified Commercial Clothes Washers"
Modified energy factor (ft^3/kWh-cycle) – Top loading	1.35	2.20	*Base case:* California Energy Commission (CEC). 2014. *2014 Appliance Efficiency Regulations.* CEC-400-2014-009-CMF. Section 1605.1, Table P-3: Standards for Commercial Clothes Washers *Measure case:* ENERGY STAR. 2018. "ENERGY STAR® Program Requirements Product Specification for Clothes Washers - Eligibility Criteria Version 8.0." Effective February 5, 2018.
Market Percent – Front Loading	30%	100%	*Base case:* U.S. Department of Energy (DOE). 2014. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Clothes Washers.* Prepared by Navigant Consulting, Inc. and Lawrence Berkeley National Laboratory. Chapter 9. *Measure case:* ENERGY STAR. 2020. "ENERGY STAR Certified Commercial Clothes Washers"
Modified energy factor (ft^3/kWh-cycle) – Front loading	2.00	2.20	*Base case:* California Energy Commission (CEC). 2014. *2014 Appliance Efficiency Regulations.* CEC-400-2014-009-CMF. Section 1605.1, Table P-3: Standards for Commercial Clothes Washers *Measure case:* ENERGY STAR. 2018. "ENERGY STAR® Program Requirements Product Specification for Clothes Washers - Eligibility Criteria Version 8.0." Effective February 5, 2018.
Number of wash cycles per year – Multifamily common area	1,095	1,095	U.S. Department of Energy (DOE). 2014. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Clothes Washers.* Prepared by Navigant Consulting, Inc. and Lawrence Berkeley National Laboratory. Chapter 7, page 7-6.
Saturation of electric water heating (%)	Varies by utility service area.		

Parameter	Base Case Model	Measure Case Model	Source
Saturation of electric dryers (%)	Varies by utility service area.		KEMA, Inc. 2010. *2009 California Residential Appliance Saturation Survey. Volume 2: Results.* Prepared for the California Energy Commission. CC-200-2010-004. DEER2020 via READI_v2.5.1
Interactive effects multiplier	Varies by utility service area.		DEER2020 via READI_v2.5.1

Clothes Washer Capacity. The figure illustrates a trend of increasing washer capacity and decreasing number of cycles per year. Efficient washers also tend to have a larger capacity than their less efficient counterparts. To prevent these factors from skewing savings estimates, the total volume of clothes washed is assumed to be constant between the base case and measure case washer; a washer capacity of 3.1 cubic feet is used for all calculations. This corresponds to 295 cycles per year, which is the same frequency assumed for residential single-family applications. Normalizing energy use to 3.1 cubic feet allows for accurate comparison of energy use between the base and measure case models, and for accurate estimation of unit energy savings.

Annual Wash Cycles / Average Wash Tub Capacity

Modified Energy Factor (MEF). The MEF assumption for the base case for both top and front-loading models is the minimum MEF allowable by state and federal appliance standard. The MEF for the ENERGY STAR front loading models (measure case) is based upon the ENERGY STAR specification Version 8.0.

To estimate the average UES for all commercial clothes washers, this analysis developed a weighted average of the base and measure case models. The DOE 2014 commercial clothes washers TSD (chapter 9) contains baseline market share saturations for commercial clothes washers. The TSD reports commercial clothes washer baseline market saturations are 70% top-loaders and 30% front-loaders. The 2014 DOE TSD (chapter 9) identified the maximum technologically feasible level ("max-tech") for top-loading commercial clothes washers to be 1.85 MEF, which is substantially lower than the 2.2 MEF minimum efficiency level required by the ENERGY STAR specification. Less than 1% of washers in the ENERGY STAR commercial clothes washer qualifying products list are top-loaders. Therefore, the market

saturation of ENERGY STAR commercial clothes washers is assumed to be comprised of 100% front-loaders.

Clothes Washer Energy Use, by End Use. The total energy use per wash cycle estimates were drawn from the DOE TSD[5] and assume the use of an electric dryer and electric domestic hot water. DOE tested a representative sample of five front-loading commercial clothes washers using both Appendix J1 and Appendix J2 test procedures. DOE used the results from these tests to determine the Appendix J2 MEF_J2/IWF ratings in relation to the Appendix J1 MEF/WF ratings for each model. The resulting energy use breakdown between washing machine, dryer, and water heater energy consumption, are provided below.

Commercial Clothes Washer Total Unit Energy Consumption by End Use

Clothes Washer Configuration	Machine Type	Clothes Washer (pctCW)	Clothes Dryer (pctDryer)	Water Heater (pctDHW)	Total
Front Loading	Base case	6.9%	80.0%	13.1%	100.0%
Front Loading	Measure case	4.3%	79.4%	16.3%	100.0%
Top Loading	Base Case	9.2%	68.8%	22.0%	100.0%
Top Loading	Measure Case	n/a	-	-	-

Saturation of Electric Water Heating and Electric Dryers. The energy use estimates from the DOE TSD assume the use of an electric water heater and an electric dryer. Thus, the calculated UEC must account for the saturation of electric hot water heating and electric dryers in California.

In 2009, the California Energy Commission administered the Residential Appliance Saturation Study (RASS)[6] across the service territories of the large investor-owned utilities (IOUs). The survey requested households to provide information on appliances, equipment, and general consumption patterns. Data collection was completed in early 2010.

The 2009 RASS data was analyzed to estimate the residential electric and gas water heater and dryer saturations for residential homes in California. Note that this analysis used the residential saturations from RASS for commercial washers installed in multifamily common areas washers because no other comparable source was available for those applications.

The weighting factors for DEER2020 clothes washers were pulled from Remote Ex-Ante Database Interface (READI) tool, a user interface that allows access to current and historical DEER data and compared to the 2009 RASS data. The data matched up well, but DEER and RASS weighting were based on IOU service territory, not climate zone. This data based on service territory was then combined with a chart comparing climate zone to the IOU most reflective of the customer base in that service territory to extrapolate the IOU specific weighting into 16 different climate zones weights. These calculated savings

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[5] U.S. Department of Energy (DOE). 2014. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Clothes Washers.* Prepared by Navigant Consulting, Inc. and Lawrence Berkeley National Laboratory. Chapter 7, Table 7.2.2 and Table 7.2.3

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

were then compared to the DEER outputs for percent gas and percent electric savings to confirm IOU assumptions were accurate. See the tables below for data and assumptions.

Residential Dryer and Water Heater Saturations, by Utility Service Area and Fuel Type

IOU Service Area	Building Type	Gas Dryer w/ Gas Water Heating	Gas Dryer w/ Elec Water Heating	Electric Dryer w/ Gas Water Heating	Electric Dryer w/ Electric Water Heating
PG&E	DMo	31.6%	8.1%	48.0%	12.3%
	MFm	28.7%	4.5%	57.7%	9.1%
	SFm	38.6%	3.9%	52.2%	5.3%
SCE	DMo	70.6%	6.1%	21.5%	1.8%
	MFm	51.3%	6.6%	37.3%	4.8%
	SFm	78.1%	2.6%	18.7%	0.6%
SDG&E	DMo	67.4%	2.7%	28.7%	1.2%
	MFm	25.6%	6.9%	53.2%	14.3%
	SFm	66.2%	2.8%	29.7%	1.3%
SCG	DMo	76.1%	2.9%	20.2%	0.8%
	MFm	60.5%	2.4%	35.7%	1.4%
	SFm	81.6%	0.7%	17.5%	0.2%

Residential Dryer and Water Heater Saturations, Utility Weight used by Climate Zone

Climate Zone	IOU Weight Used
CZ01	PGE
CZ02	PGE
CZ03	PGE
CZ04	PGE
CZ05	PGE
CZ06	SCE
CZ07	SDG
CZ08	SCE
CZ09	SCE
CZ10	SCE
CZ11	PGE
CZ12	PGE
CZ13	PGE
CZ14	SCE
CZ15	SCE
CZ16	SCE

Interactive Effects Multiplier. The interactive effects multipliers were drawn from DEER2020. Because interactive effects factors specific to clothes washers were not available, the HVAC interactive effects factors for screw-in lamps were applied to the clothes washer measure savings. The interactive effects

factors were selected for "Res" Building type for each California climate zone and the "Existing" and "New" building vintages.

PEAK ELECTRIC DEMAND REDUCTION (KW)

Residential Clothes Washers – DEER-based Peak Demand Reduction

As with electric energy savings, the peak demand reduction of residential ENERGY STAR clothes washers was drawn directly from the Database of Energy Efficient Resources (DEER). The measure offerings for which the values were drawn directly from DEER are specified below. The DEER Measure IDs in this table are only applicable to residential clothes washers installed in single-family, double-wide mobile home, and in-unit multifamily residences.

Clothes Washer DEER Measure IDs

Tier	Measure Offering	DEER Measure ID	Min. Integrated Modified Energy Factor (IMEF)	Max. Integrated Water Factor (IWF)
ENERGY STAR – Residential	ENERGY STAR Top-Loading > 2.5 ft^3	RB-Appl-EffCW-med-Tier1-Top	2.06	4.3
	ENERGY STAR Front-Loading > 2.5 ft^3	RB-Appl-EffCW-med-Tier2-Front	2.76	3.2
ENERGY STAR Most Efficient (ESME) – Residential	Top-Loading > 2.5 ft^3	Scaled from RB-Appl-EffCW-med-Tier3-Front	2.92	3.2
	Front-Loading > 2.5 ft^3	RB-Appl-EffCW-med-Tier3-Front		

Commercial Clothes Washers – Non-DEER Peak Demand Reduction

The peak demand reduction for a commercial clothes washer is represented by the following.

$$PeakDemandReduction = \left[\frac{UES_{elec} \times CDF}{DAYS}\right] \times IE$$

$UES_{elec} =$	*Electric unit energy savings (see Electric Savings section)*
$CDF =$	*Coincident demand factor*
$Days =$	*Operating days per year*
$IE =$	*Demand interactive effects multiplier*

Coincident Demand Factor. The coincident demand factor (CDF) was drawn from the U.S. DOE Office of Energy Efficiency and Renewable Energy Building Analysis Spreadsheets developed as companion resources for the House Simulation Protocols. The Building America Existing Homes spreadsheet provides the set of standard operating conditions—including hourly and monthly profiles for occupancy, lighting, appliances, and miscellaneous electric loads developed by Building America to objectively compare energy use before and after a retrofit.

Peak Demand Reduction Inputs

End Use	CDF	Source
Multifamily Common Area	0.067	U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy. 2010. Building America Analysis Spreadsheets. "B10 Analysis - Existing Homes 2011.01.26.xlsm." See "Pre-Retrofit Normalized Hourly Profiles (Common Areas)" on the "Hourly Profiles" tab. Last modified December 17, 2010.

Interactive Effects Multiplier. The interactive effects multipliers were drawn from DEER2020. Because interactive effects factors specific to clothes washers were not available, the HVAC interactive effects factors for screw-in lamps were applied to the clothes washer measure savings. The interactive effects factors were selected for "Res" Building type for "IOU territory" (weighted by climate zone) and the "Existing" and "New" building vintages. The factors for the utilities were used for the appropriate climate zone as described in the section above.

GAS SAVINGS (THERMS)

The natural gas unit energy savings (UES) of an efficient clothes washer is based solely on the energy savings associated with reduced gas hot water heater and gas dryer energy consumption that will result from the installation of a high-efficiency clothes washer. The approaches to estimate the gas UES for residential clothes washers are summarized below.

Residential Clothes Washers – DEER-Based Unit Energy Savings

As with electric energy savings, the gas UES of residential ENERGY STAR clothes washers was drawn directly from the Database of Energy Efficient Resources (DEER). The measure offerings for which the values were drawn directly from DEER 2018 are specified below. The DEER Measure IDs in this table are only applicable to residential clothes washers installed in single-family, double-wide mobile home, and in-unit multifamily residences.

Clothes Washer DEER Measure IDs

Tier	Measure Offering	DEER Measure ID	Min. Integrated Modified Energy Factor (IMEF)	Max. Integrated Water Factor (IWF)
ENERGY STAR – Residential	ENERGY STAR Top-Loading	RB-Appl-EffCW-med-Tier1-Top	2.06	4.3
	ENERGY STAR Front-Loading > 2.5 ft^3	RB-Appl-EffCW-med-Tier2-Front	2.76	3.2
ENERGY STAR Most Efficient (ESME) – Residential	Top-Loading > 2.5 ft^3	Scaled from RB-Appl-EffCW-med-Tier3-Front	2.92	3.2
	Front-Loading > 2.5 ft^3	RB-Appl-EffCW-med-Tier3-Front		

Commercial Clothes Washers – Non-DEER Unit Energy Savings

Clothes washers for which UES are not available in DEER include all commercial models. The methodology for calculating the UES and an explanation of the parameters in the calculation are provided below.

Non-DEER Based Commercial Clothes Washers

Tier	Measure Offering	Min. Modified Energy Factor (MEF J2)	Max. Integrated Water Factor (IWF)
ENERGY STAR Commercial	ENERGY STAR Commercial Clothes Washer – Coin Operated	2.20	4.0
	ENERGY STAR Commercial Clothes Washer – Leased		

Fundamentally, the UES is equal to the difference between the base case and the measure case unit energy consumption (UEC). The UEC difference is then multiplied by the product of the electric UES and an interactive effects multiplier to account for the change in electric energy use by the HVAC system due to a change space heating/cooling needs.

$$UES_{gas} = [UEC_{gas\,base} - UEC_{gas\,measure}] + [UES_{elec}] \times IE$$

The UEC of a clothes washer (baseline or measure) is a function of the energy requirements of the washing machine itself, and the energy requirements of the water heater and clothes dryer; and further assumes that those end uses are electrically powered. These parameters reflect the breakdown of the per-wash cycle energy use by end use. In other words, the gas energy savings for a commercial clothes washer must be parsed out into these distinct end uses that are affected by the efficient clothes washer. Further, to acknowledge that the saturation of gas water heating and gas dryers is not 100%, the UEC calculation includes the saturation of electric water heating and electric dryers in the market.

$$UEC_{gas} = CAP\left(\frac{1}{MEF}\right) \times C_1 \times N \\ \times [(pctDHW \times pctDWH_{gas} \times \text{CorrGasDHW}) + (pctDryer \times pctDryer_{gas} \times \text{CorrGasDryer})]$$

CAP =	*Capacity of clothes washer (ft³)*
MEF =	*MEF of clothes washer, base or measure case (ft³/kWh-wash cycle)*
C₁ =	*Constant kWh to Therm conversion factor - 3412 Btu/kWh) / 100,000 BTU/Therm*
N =	*Number of wash cycles per year*
pctDHW =	*Portion of energy usage attributable to hot water heater, base or measure case (%)*
pctDryer =	*Portion of energy usage attributable to clothes dryer (%)*
pctDHW_gas =	*Saturation of gas water heating (%)*
pctDryer_gas =	*Saturation of gas dryers (%)*
CorrGasDHW =	*Gas correction factor for water heater*
CorrGasDryer =	*Gas correction factor for dryer*

Electric (kWh) to Gas (therm) Conversion. The energy use estimates taken from the U.S. Department of Energy (DOE) Technical Support Documents (TSDs) assume the use of an electric dryer and electric hot water heater. Because the energy usage is expressed exclusively in kWh, the dryer and water heater

energy use values were converted to therms for the domestic hot water and dryer combinations that include gas as a fuel source.

Gas Correction Factors. Gas energy savings estimates were developed for the following domestic hot water and dryer combinations: electric water heat / electric dryer, gas water heat / electric dryer and gas water heat / gas dryer. According to the 2009 RASS, 0% of California IOU customers have electric water heat / gas dryer combinations in their homes. RASS distributions are considered separately for PG&E, SCE, SCG, and SDG&E customers. Because gas dryers and gas water heaters have a lower energy factor than electric dryers and electric water heaters, correction factors must be applied to facilities with gas dryers and/or gas water heating.

The gas water heater (or gas dryer) correction factor is a ratio of the efficiency of an electric storage water heater (or electric dryer) to the efficiency of a gas storage water heater (or gas dryer).

Gas Correction Factors

Factor	Value	Source
Gas Dryer Correction Factor	1.120	U.S. Department of Energy (DOE). 2012. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Clothes Washers.* Prepared by Navigant Consulting, Inc. and Ernest Orlando Lawrence Berkeley National Laboratory.
Efficiency of electric water heater	1.000	
Efficiency of gas water heater	0.770	
Gas Water Heater Correction Factor	1.333	

Interactive Effects Multiplier. The interactive effects multipliers were drawn from DEER2020. Because interactive effects factors specific to clothes washers were not available, the HVAC interactive effects factors for screw-in lamps were applied to the clothes washer measure savings. The interactive effects factors were selected for "Res" Building type for "IOU territory" (weighted by climate zone) and the "Existing" and "New" building vintages. The factors for the utilities were used for the appropriate climate zone as described in the section above.

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 EUL specified for high-efficiency clothes washers are presented below.

Effective Useful Life and Remaining Useful Life

Parameter	Residential		Commercial		Source
	ENERGY STAR Top and Front Loading > 2.5 cubic feet	ENERGY STAR Most Efficient Top and Front Loading > 2.5 cubic feet	ENERGY STAR Front Loading Clothes Washer	ENERGY STAR Front Loading Clothes Washer (Leased)	
EUL (yrs)	11.0	11.0	11.0	5.0	California Public Utilities Commission (CPUC). 2014. "DEER2014-EUL-table-update_2014-02-05.xlsx."
RUL (yrs)	n/a	n/a	n/a	n/a	-

BASE CASE MATERIAL COST ($/UNIT)

Residential Clothes Washers

The base case material cost for equipment *delivered via direct install* is equal to $0.

The estimation of the base case material cost for *all other delivery types* was estimated with regression analysis of model data obtained by Energy Solutions, under contract with PG&E in November 2016, to determine the incremental measure cost (IMC) of a high efficiency residential clothes washer. A web scraping tool collected data on cost and other product attributes of clothes washers from five major retailers; washer models were matched to the ENERGY STAR qualified product list (QPL),[7] the California Energy Commission (CEC) Modernized Appliance Efficiency Database System (MAEDBS),[8] and the U.S. Department of Energy (DOE) Compliance Certification Database – all accessed in 2016.[9] Using a multiple regression analysis, the study team identified the incremental cost of the measure features that improve efficiency (represented by the IMEF value).

Commercial Clothes Washers

The base case material cost for equipment *delivered via direct install* is equal to $0.

The material cost for *all other delivery types* was derived from the 2014 DOE Technical Support Document (TSD) in rulemaking EERE-2012-BT-STD-0020-0036.[10] The production and materials costs for both top- and front-loading commercial washers were obtained from Chapter 5 of the TSD. The sum of the production cost and material cost represents the total manufacturing cost. The base case top-and front-

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[7] https://www.energystar.gov/productfinder/product/certified-clothes-washers/results

[8] https://cacertappliances.energy.ca.gov/Pages/ApplianceSearch.aspx

[9] https://www.regulations.doe.gov/certification-data/CCMS-79223002113.html#q=Product_Group_s%3A%22Clothes%20Washers%20-%20Residential%22

[10] U.S. Department of Energy. 2014. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Clothes Washers*. Prepared by Navigant Consulting, Inc. and Lawrence Berkeley National Laboratory.

loading market saturations are applied to obtain a weighted manufacturing cost. Chapter 6 of the TSD contains manufacturer and distributor markups that were applied to the manufacturing cost to derive the cost to the consumer.

$$Total\ Material\ Cost_{base}$$
$$= \{[pctMktPen_{top} \times (ProdCost_{top} + MatCost_{top})]$$
$$+ [pctMktPen_{front} \times (ProdCost_{front} + MatCost_{front})]\} \times MfrMarkup \times DistMarkup$$

MEASURE CASE MATERIAL COST ($/UNIT)

Residential Clothes Washers

The estimation of the material cost for *all delivery types* was estimated with regression analysis of model data obtained by Energy Solutions, under contract with PG&E in November 2016, to determine the incremental measure cost (IMC) of a high efficiency residential clothes washer. A web scraping tool collected data on cost and other product attributes of clothes washers from five major retailers; washer models were matched to the ENERGY STAR qualified product list (QPL),[11] the California Energy Commission (CEC) Modernized Appliance Efficiency Database System (MAEDBS),[12] and the U.S. Department of Energy (DOE) Compliance Certification Database – all accessed in 2016.[13] Using a multiple regression analysis, the study team identified the incremental cost of the measure features that improve efficiency (represented by the IMEF value).

Note that at the time of this analysis (November 2016), the ENERGY STAR specification was different from the current ENERGY STAR specification (2018). However, the minimum IMEF requirements remained consistent. The mapping from the prior and current ENERGY STAR specifications is as follows:

Front-Loaders:

IMEF ≥ 2.76: 2016 ENERGY STAR Most Efficient = 2018 ENERGY STAR

IMEF ≥ 2.72: 2016 CEE Tier 3 = 2018 ENERGY STAR Most Efficient

Top-Loaders:

IMEF ≥ 2.06: 2016 ENERGY STAR = 2018 ENERGY STAR

IMEF ≥ 2.76: 2016 CEE Tier 3 = 2018 ENERGY STAR Most Efficient

For consistency, this measure will refer to the 2018 ENERGY STAR specifications.

The IMC was derived using the multiple regression analysis shown using data from five major retailer websites:

$$Log(Price) = \beta_0 + \beta_1 IMEF + \beta_2 IMEF[Attribute_2] \dots + \beta_n IMEF[Attribute_n] + \varepsilon$$

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[11] https://www.energystar.gov/productfinder/product/certified-clothes-washers/results

[12] https://cacertappliances.energy.ca.gov/Pages/ApplianceSearch.aspx

[13] https://www.regulations.doe.gov/certification-data/CCMS-79223002113.html#q=Product_Group_s%3A%22Clothes%20Washers%20-%20Residential%22

The resulting regression coefficient for IMEF is 0.49. The IMC is calculated as:

$$IMC = Cost_{base} * exp(\beta_{IMEF} * \Delta IMEF) - Cost_{base}$$

$Cost_{base} =$ *Base case cost (\$)*

$\Delta IMEF =$ *Difference between the average IMEF of ENERGY STAR only models and the average IMEF of non-ENERGY STAR models.*

Due to different market characteristics between front-loading and top-loading clothes washers, a separate IMC analysis was conducted for each type.

Commercial Clothes Washers

The material cost of a measure case commercial clothes washer for *all delivery types* was derived from the base case costs derived from the 2014 DOE Technical Support Document (TSD) in rulemaking EERE-2012-BT-STD-0020-0036.[14] [15] The production and materials costs for base case top- and front-loading commercial washers were obtained from Chapter 5 of the TSD. The sum of the production cost and material cost represents the total manufacturing cost. The measure case top-and front-loading market saturations are applied to obtain a weighted manufacturing cost. Chapter 6 of the TSD contains manufacturer and distributor markups that were applied to the manufacturing cost to derive the cost to the consumer. Note that the distributor markup is lower for the measure case than the base case and thereby reflects the change in the manufacturer sales price of higher efficiency models to the change in the distributor price.

$$Total\ Material\ Cost_{measure}$$
$$= \{[pctMktPen_{top} \times (ProdCost_{top} + MatCost_{top})]$$
$$+ [pctMktPen_{front} \times (ProdCost_{front} + MatCost_{front})]\} \times MfrMarkup \times DistMarkup$$

BASE CASE LABOR COST ($/UNIT)

The base case labor cost for equipment *delivered via direct install* is equal to \$0.

For *all other delivery types*, it is assumed the participant would have purchased a standard efficiency clothes washer absent the program. As such, the labor cost is assumed to be the same for both base case and measure case scenarios and the incremental labor cost is equal to \$0.

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[14] U.S. Department of Energy. 2014. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Clothes Washers*. Prepared by Navigant Consulting, Inc. and Lawrence Berkeley National Laboratory.

[15] Pacific Gas and Electric (PG&E). 2018. "Clothes Washer_Cost_PGECOAPP127 R4.xls."

MEASURE CASE LABOR COST ($/UNIT)

For *all other delivery types*, it is assumed the participant would have purchased a standard efficiency clothes washer absent the program. As such, the labor cost is assumed to be the same for both base case and measure case scenarios and the incremental labor cost is equal to $0.

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 established for residential clothes washers is applicable for all units with a modified energy factor (MEF) that exceeds the ENERGY STAR qualification by 10%.

Net-to-Gross Ratios

Parameter	Residential		Commercial		Source
	ENERGY STAR Top and Front Loading > 2.5 cubic feet	ENERGY STAR Most Efficient Top and Front Loading > 2.5 cubic feet	ENERGY STAR Front Loading Clothes Washer	ENERGY STAR Front Loading Clothes Washer (Leased)	
NTG – residential units with MEF ≥ 10% above ENERGY STAR	0.31	0.31	0.31	0.31	Itron, Inc. 2011. *DEER Database 2011 Update Documentation.* Prepared for the California Public Utilities Commission. Page 14-5 Table 14-3.

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	Residential		Commercial		Source
	ENERGY STAR Top and Front Loading > 2.5 cubic feet	ENERGY STAR Most Efficient Top and Front Loading > 2.5 cubic feet	ENERGY STAR Front Loading Clothes Washer	ENERGY STAR Front Loading Clothes Washer (Leased)	
GSIA	1.0	1.0	1.0	1.0	California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 31.

NON-ENERGY IMPACTS

The non-energy impacts associated with a high-efficiency clothes washer is the reduction in water use. The water savings for this measure were derived only for the residential models that meet the ENERGY STAR Most Efficient specification. This includes ENERGY STAR Most Efficient models installed in single family and in-unit multifamily residences, as well as residential clothes washers installed in multifamily common areas.

The water savings for the residential ENERGY STAR Most Efficient clothes washers were calculated with the Water Energy Nexus Calculator (WEN Calculator version 1.05), a calculator designed to calculate the embedded energy in water and the avoided capacity cost associated with water savings.[16] The "Environmental Benefits" module within the WEN Calculator calculates reduced water use from secondary data of existing environmental benefits models.

DEER DIFFERENCES ANALYSIS

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

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[16] California Public Utilities Commission (CPUC). 2015. *Decision 15-09-023 in the Order Instituting Rulemaking into Policies to Promote a Partnership Framework between Investor Owned Utilities and the Water Sector to Promote Water-Energy Nexus Programs (R.13-12-011).* Issued September 25, 2015.

DEER Difference Summary

DEER Item	Comment
Modified DEER methodology	Yes
Scaled DEER measure	Yes
DEER Base Case	Yes
DEER Measure Case	Yes
DEER Building Types	Yes
DEER Operating Hours	Yes
DEER eQUEST Prototypes	No
DEER Version	DEER 2020 READi v2.5.1
DEER Measure IDs Used	RB-Appl-EffCW-med-Tier1-Top RB-Appl-EffCW-med-Tier3-Top (*scaled up to meet ENERGYSTAR most efficient criteria*) RB-Appl-EffCW-med-Tier2-Front RB-Appl-EffCW-med-Tier3-Front
NTG	Source: DEER 2011. The value of 0.31 is associated with NTG ID: *Res-sAll-mCW*
GSIA	Source: DEER. The value of 1.0 is associated with GSIA ID: *Def-GSIA*
EUL/RUL	Source: DEER. The value of 11 years is associated with EUL IDs: *ComLau-EffCW and Appl-Eff-CW* The value of 5 years is associated with EUL IDs: *ComLau-EffCW-Leased*

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision Effective Date and Approved By
01	02/28/2018	Jennifer Holmes Cal TF Staff	Draft of consolidated text for this statewide measure is based upon: PGECOAPP127, Revision 4 (December 18, 2017) PGECOAPP127, Revision 3 (January 13, 2017) Consensus reached among Cal TF members.
	12/31/2018	Jennifer Holmes Cal TF Staff	Revisions for submittal of Version 01
	07/02/2019	Ayad Al-Shaikh, Cal TF Staff	Update DEER Table.
02	9/10/2020	Adan Rosillo, PG&E Anders Danryd, SoCalGas	Updated from DEER 2017 to DEER 2020 savings values Added commercial laundry units in multifamily common area, updated savings from IOU specific savings to CZ specific savings.
	9/15/2020	Anders Danryd, SoCalGas	Fixed issue with Energy impact tab having the wrong label for one measure, minor text edits, fixed table on content page numbers
	10/27/2020	Anders Danryd, SoCalGas	Updated workpaper and EAD tables for missing climate zones in the DEER data.
	01/22/2021	Anders Danryd, SoCalGas	Fixed error where ESME Top load washers were mapped to the wrong savings, updated interactive effects to CZ from IOU loc.
	03/24/2021	Soe K Hla PG&E	Adopted all remaining measures for PG&E