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FOOD SERVICE

COMMERCIAL DISHWASHER

SWFS002-01

CONTENTS

MEASURE NAME

Commercial Dishwasher, Door-type

STATEWIDE MEASURE ID

SWFS002-01

TECHNOLOGY SUMMARY

Commercial dishwashers are used in many commercial establishments to clean and sanitize non-disposable dishes, glassware, and utensils, such as restaurants, bars, schools, hospitals, nursing homes, churches, and institutional cafeterias. The commercial dishwasher cleans and sanitizes a large quantity of kitchen wares in a short time by utilizing hot water, soap, rinse chemicals, and significant amounts of energy. Size requirements for commercial dishwashing machines are calculated by estimating the number of individuals served by the food service establishment. This information is a key determinant of the type of dishwasher that is most suited for a specific facility.

This measure includes both low-temperature and high-temperature sanitization units. A low-temperature commercial dishwasher is intended to use water that is solely heated by an external gas or electric water heater and must meet the National Sanitation Foundation (NSF) mandated sanitation criteria via a final rinse chemical sanitizing solution that follows the wash cycle. A high-temperature dishwasher reuses wash water from the dishwashing water tank for the wash cycle and then additional clean water for the rinse cycle that is raised to 180 °F via a gas or electric booster heater. Rinse water is then collected and used to overflow the wash water tank providing heat recovery and a fresh water stream.

The differences between a low- and high-temperature sanitization method affects the unit energy consumption (UEC). For a low-temperature unit, 90% of the energy used is associated with primary water heating, with the remaining 10% attributed to auxiliary components and standby energy.[1] For a high-temperature unit, 64% of the total energy consumption is used for primary water heating, 25% is for booster water heating, and the remaining 12% is attributed to the motor, wash tank heater, controls, and standby energy.[2] It is assumed that the motors and controls components do not vary significantly between standard and high-efficiency models.

Water consumption, and therefore water heating requirements, varies significantly between a standard and high-efficiency unit and is the primary contributor of the unit energy savings (UES). A high-efficiency commercial dishwasher reduces water heating requirements while maintaining cleaning performance by reducing heat losses, improving mechanical soil removal, and/or increasing component efficiencies. By using strategies such as waste air heat recovery, drain heat recovery, rinse water re-use, double-walled insulated construction, high-efficiency anti-clogging nozzles, continuous filtering, and efficient boost heaters, water consumption can be reduced from as high as four to five gallons per rack (GPR) to less than one-half GPR, depending on the type of dishwasher.

[1] The source of this data is unknown.

[2] The source of this data is unknown.

An ENERGY STAR®-qualified commercial dishwasher is on average 40% more energy efficient and 40% more water efficient than a standard model.[3] ENERGY STAR-qualified models include both low- and high-temperature models and must meet maximum water consumption requirements and use less energy while idling between wash cycles.

MEASURE CASE DESCRIPTION

The measure case specification is based upon the Tier 2 ENERGY STAR® specification for door-type commercial dishwashers (based on 15% below the ENERGY STAR Commercial Dishwashers, Version 2.0).

Measure Case Specification

Sanitization Temperature	Max. Water Consumption (GPR)	Max. Idle Energy Rate (kW)	Source
High Temperature	0.76	0.70	ENERGY STAR. 2012. "ENERGY STAR Program Requirements for Commercial Dishwashers. Eligibility Criteria (Rev. June 2012) Version 2.0." Effective February 1, 2013.
Low Temperature	1.00	0.60	

The ENERGY STAR Test Method for Commercial Dishwashers follows the American Society for Testing and Materials (ASTM) F1696-07 Standard Test Method for Energy Performance Single-Rack, Door-Type Commercial Dishwashing Machines[4] to estimate the energy and water consumption of ENERGY STAR-qualified units.

BASE CASE DESCRIPTION

The base case commercial door-type dishwasher is defined as the existing door-type commercial dishwasher, considered to be the industry standard practice. The base case specifications for this measure were derived as the average of field data collected from five different commercial food service sites and the minimum ENERGY STAR commercial door-type dishwasher specification.

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[3] ENERGY STAR. 2017. "Commercial Dishwashers." http://www.energystar.gov/products/certified-products/detail/commercial-dishwashers. Accessed on July 26.

[4] American Society for Testing and Materials (ASTM). 2007. *ASTM F1696-07 Standard Test Method for Energy Performance Single-Rack, Door-Type Commercial Dishwashing Machines.* West Conshohocken (PA): ASTM International.

Base Case Specification

Sanitization Temperature	Max. Water Consumption (GPR)	Max. Idle Energy Rate (kW)	Source
High Temperature	1.07	0.70	ENERGY STAR. 2012. “ENERGY STAR Program Requirements for Commercial Dishwashers. Eligibility Criteria (Rev. June 2012) Version 2.0.” Effective February 1, 2013. Pacific Gas and Electric (PG&E). 2015. "Dishmachine Calcs 02092015.xls."
Low Temperature	1.50	0.60	

CODE REQUIREMENTS

This measure is not governed by either state or federal codes and standards.

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

The ENERGY STAR Test Method for Commercial Dishwashers uses the American Society for Testing and Materials (ASTM) F1696-07 Standard Test Method for Energy Performance Single-Rack, Door-Type Commercial Dishwashing Machines[5] to estimate the energy and water consumption of both the base and measure case models.

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

[5] American Society for Testing and Materials (ASTM). 2007. *ASTM F1696-07 Standard Test Method for Energy Performance Single-Rack, Door-Type Commercial Dishwashing Machines.* West Conshohocken (PA): ASTM International.

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 for Investor-Owned Utilities

Measure Application Type	Delivery Type	Sector
Normal replacement	DnDeemed	Ag
Normal replacement	DnDeemed	Ind
Normal replacement	DnDeemed	Com
Normal replacement	DnDeemDI	Ag
Normal replacement	DnDeemDI	Ind
Normal replacement	DnDeemDI	Com
Normal replacement	UpDeemed	Ag
Normal replacement	UpDeemed	Ind
Normal replacement	UpDeemed	Com
New construction	DnDeemed	Ag
New construction	DnDeemed	Ind
New construction	DnDeemed	Com
New construction	DnDeemDI	Ag
New construction	DnDeemDI	Ind
New construction	DnDeemDI	Com
New construction	UpDeemed	Ag
New construction	UpDeemed	Ind
New construction	UpDeemed	Com

Eligible Products

This measure includes new commercial low- and high-temperature door-type dishwashers that meet the efficiency requirements presented in the Measure Case Description.

Eligible Building Types and Vintages

This measure is applicable for any nonresidential building type of any vintage.

Eligible Climate Zones

This measure is applicable in any California climate zone.

PROGRAM EXCLUSIONS

Used or rebuilt equipment and other dishwasher types (conveyor, under-counter, flight-type) are not eligible.

DATA COLLECTION REQUIREMENTS

Data collection requirements are to be determined.

USE CATEGORY

Appliance and plug load (AppPlug)

ELECTRIC SAVINGS (kWh)

The basis for electric unit energy savings (UES) is the difference between the water heating unit energy consumption (UEC) of the base case and measure case dishwasher models. Because energy-efficient units require considerably less water, less energy is required for water heating. For both low- and high-temperature machines, the base case UEC is based on the energy required to heat water for the dishwashing and sanitizing cycles. The high-temperature unit water heating energy components are further split into *primary* and *booster* water heating.

The calculation of the annual electric UEC is calculated as the difference between the baseline UEC and the measure case UEC. Note that motor energy and standby losses are assumed to be the same for both the base case and the measure case and are therefore not presented in the energy savings calculations.

$$UEC\_YEAR = Electric\ Water\ Heater\ Energy + Booster\ Water\ Heater\ Energy + Idle\ Energy$$

Each term in the UEC calculation is detailed below, followed by all inputs and assumptions.

Electric Water Heater Energy Use

Electric water heater energy use is a function of water consumption (GPR), the number of racks washed per year, the UEC per gallon of water, and market penetration of electric water heating and booster heating.

$$Electric\ \ Water\ Heater\ Energy = GPR \times RACKS \times EDAYS \times UECGAL \times MktPen_{elec}$$

$GPR = Water\ consumption\ (GPR)$
$RACKS = Number\ of\ racks\ washed\ per\ day\ (\#)$
$EDAYS = Operating\ days\ per\ year\ (days)$
$UECGAL = UEC\ per\ gallon\ of\ water\ (kWh)$
$MktPen = Market\ penetration\ of\ electric\ water\ heating\ (\%,\ decimal)$

Water Consumption (GPR). The National Sanitation Foundation (NSF) provides a database of commercial dishwashers that reports manufacturer calculated water consumption in gallons per rack (GPR).[6] The

[6] National Sanitation Foundation (NSF). (n.d.) NSF/ANSI 3 - Commercial Warewashing Equipment. "Com Dishwashers NSF Energy Star.xlsx."

database includes models that meet the ENERGY STAR performance criteria[7] for reduced water consumption (1.18 GPR for low-temperature units, and 0.95 GPR for high-temperature units), even models that qualify but for which the ENERGY STAR label was not pursued. The water and energy consumption calculations for this measure exclude models that are no longer manufactured.

Racks per Year. The number of racks per year is equal to the number of racks per day multiplied by the assumed number of days of operation per year.

Racks per Day. The number of racks per day is based on monitored data from five different restaurant sites (fast casual, fine dining, cafes, and quick service restaurants) and dishwasher leasing companies that track the racks per month as part of the equipment lease agreements. The monitored data was provided by the Food Service Technology Center (FSTC).[8]

UEC per Gallon of Water. The UEC per gallon of water is based on the increase in water temperature required for a wash cycle, the specific heat of water, the weight of water, and the heating equipment efficiency.

$$UECGAL = \left(\frac{\Delta T \times C \times \rho}{\eta}\right) \times \frac{kWh}{Btu}$$

ΔT = *Temperature rise (°F)*

C = *Specific heat of water, the energy required to raise one pound of water by one-degree, constant* $\left(\frac{Btu}{lb-°F}\right)$

ρ = *Density of water, constant* $\left(\frac{lbs}{gal}\right)$

η = *Electric heating equipment efficiency*

kWh/Btu = *Btu to kWh conversion factor*

The parameters to calculate the UEC per gallon of water are explained below.

Temperature rise (°F) – This analysis assumes an average inlet water temperature of 61 °F that needs to be raised to 140 °F to meet the minimum supply water temperature at the dishwasher. The average inlet water temperature is calculated as the average annual ground water temperature across all California climate zones. This water heating requirement applies to both low- and high-temperature machines. For high-temperature machines, there is an extra sanitizing rinse that increases the water temperature via a dishwasher booster water heater an additional 40 °F, to 180 °F to meet the National Sanitation Foundation (NSF) mandated sanitation criteria. (The low-temperature machines meet this standard via a chemical rinse).

Electric heating equipment efficiency (%) – Heating equipment efficiency varies between electric and gas units, as well as between external primary water heating and internal booster heating.

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[7] ENERGY STAR. 2012. "ENERGY STAR Program Requirements for Commercial Dishwashers. Eligibility Criteria (Rev. July 2012) Version 2.0." Effective February 1, 2013.

[8] Pacific Gas and Electric (PG&E). 2015. "Dishmachine Calcs 09092015.xls."

The assumptions of water heating equipment efficiency conform to the California Public Utility Commission (CPUC) Energy Division disposition for water fixtures issued in February 2013.[9]

Booster heating unit efficiency is used to determine the additional energy consumption of the booster water heating in high temperature units. These engineering assumptions are consistent with those used for ENERGY STAR eligibility.[10]

Electric Booster Water Heater Energy

For a high-temperature unit using a higher-temperature sanitizing rinse, the methodology was used to determine the additional energy required for the booster water heating as was followed for the Electric Water Heater Energy. The booster heater, however, is needed to increase 100% of the water from a temperature of 140 °F to 180 °F.

$$Electric\ \ Booster\ Heater\ Energy = GPR \times RACKS \times UECGAL \times MktPen_{booster,elec}$$

$GPR = Water\ consumption\ (GPR)$

$RACKS = Number\ of\ racks\ washed\ per\ year\ (\#)$

$UECGAL = UEC\ per\ gallon\ of\ water\ (kWh)$

$MktPen = Market\ penetration\ of\ electric\ booster\ water\ heating\ (\%,\ decimal)$

Note that a low-temperature dishwasher will not have booster heater energy as part of the calculation and this term will equal zero for the low-temperature model.

Market Penetration of Booster Heating Fuel Types. A high-temperature unit achieves energy savings via primary water heating as well as booster water heating. It is assumed that restaurants with electric primary heating will only install electric dishwashers with electric booster heating. While most restaurants with gas primary water heating are more likely to install an electric dishwasher with electric booster heating, gas booster heating is available and is installed in a small percentage of restaurants. The assumed percentages of market penetration for each primary/booster fuel combination are provided below. These percentages were applied to the primary water heating energy savings for low- and high-temperature units.

Market Penetration of Primary Water Heating and Booster Water Heating Fuel Combinations

Primary/Booster Fuel Combination	Penetration (%)	Source
Electric/Electric	3%	The source of this data is unknown.
Gas/Gas	5%	
Gas/Electric	92%	

[9] California Public Utilities Commission (CPUC), Energy Division. 2013. "Workpaper Disposition for Water Fixtures." February 22.

[10] ENERGY STAR. 2012. "ENERGY STAR Program Requirements for Commercial Dishwashers. Eligibility Criteria (Rev. July 2012) Version 2.0." Effective February 1, 2013.

Annual Idle Energy

Annual idle energy use is a function of operating hours, wash time, idle energy rate, and the market penetration of primary and booster water heating fuel types.

$$Annual\ Idle\ Energy = EDAYS \times \left(EHOURS - \frac{TWASH}{MIN}\right) \times IDLERATE$$

EDAYS=	*Estimated operating days per year (days)*
EHOUR=	*Estimated operating hours per day (hrs)*
TWASH =	*Estimated wash time per rack (min)*
MIN =	*Constant minutes per hour (min)*
IDLERATE =	*Measured idle energy rate (kW)*

Operating Hours per Day and **Operating Days per Year.** The commercial dishwasher hours and days per year of operation was derived from an independent survey of 54 food service establishments conducted by Navigant Consulting.[11] The survey sample included independent restaurants, casual concept (big chain) restaurants, and fast food chains. These assumed hours and days of operation align with assumptions for many other food service measures drawn from a food service equipment market potential study conducted for the California Energy Commission (CEC) by Fisher-Nickel, Inc.[12]

Idle Energy Rate. The idle energy rate for high-temperature and low-temperature machines is based upon the ENERGY STAR eligibility requirements in the Measure Case Description. Due to lack of research data, the idle energy rate is assumed to be the same for both the base and measure case.

Market Penetration of Booster Heating Fuel Types. See Electric Booster Water Heater Energy.

Annual Electric Unit Energy Savings

The **annual UES** is calculated as the difference between the baseline and measure case annual UEC.

$$UES_{YEAR} = [UEC\_YEAR_{Base} - UEC\_YEAR_{Measure}]$$

Inputs and Assumptions

The inputs for the calculation of the annual electric UEC for both low- and high-temperature door-type units are specified below.

Electric UEC Inputs – High-Temperature Door-Type Dishwasher

Parameter	Base Case Model	Measure Case Model	Source
Specific heat of Water (Btu/lb/°F)	1	1	
Density of Water (lb/gal)	8.2	8.2	

[11] The source for this data or information is unknown.

[12] Spoor, C., D. Zabrowski, and L. Mills. (Fisher-Nickel, Inc.) 2014. *Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Food Service Equipment.* Prepared for the California Energy Commission. CEC-500-2014-095.

Parameter	Base Case Model	Measure Case Model	Source
Inlet water Temperature (°F)	61 °F	61 °F	California Energy Commission (CEC). 2011. "CZ2010 Weather Files.xls." Average water temperature across all climate zones.
Setpoint Hot Water Temperature (°F)	140 °F	140 °F	The source for this data is unknown.
Booster Heater Water Temperature Rise (°F)	40 °F	40 °F	National Sanitation Foundation (NSF). (n.d.) NSF/ANSI 3 - Commercial Warewashing Equipment. "Com Dishwashers NSF Energy Star.xlsx."
Electric Water Heater Energy per Gallon (kWh/gal)	0.208	0.208	Pacific Gas and Electric (PG&E). 2015. "Dishmachine Calcs 02092015.xls."
Electric Booster Heater Energy per Gallon (kWh/gal)	0.101	0.101	
Electric Water Heater Efficiency (%)	95%	95%	California Public Utilities Commission (CPUC), Energy Division. 2013. "Workpaper Disposition for Water Fixtures." February 22. California Public Utilities Commission (CPUC), Energy Division. "DEER-WaterHeater-Calculator-v1.0.xlsm."
Electric Water Booster Heater Efficiency (%)	95%	95%	
Number of Racks per day (racks/day)	140.5	140.5	Pacific Gas and Electric (PG&E). 2015. "Dishmachine Calcs 02092015.xls." See "Monitored Data + GPR" tab.
Water Consumption (Gal/Rack)	1.06	0.60	National Sanitation Foundation (NSF). (n.d.) NSF/ANSI 3 - Commercial Warewashing Equipment. "Com Dishwashers NSF Energy Star.xlsx."
Daily Water Consumption (gal)	149	84	Calculated = Racks per Day x Gal/Rack
Daily Booster Consumption (gal)	149	84	Calculated = Racks per Day x Gal/Rack
Wash time per rack (min/rack)	1	1	The source for this data is unknown.
Idle Energy Rate (kW)	0.7	0.7	ENERGY STAR. 2012. "ENERGY STAR Program Requirements for Commercial Dishwashers. Eligibility Criteria (Rev. July 2012) Version 2.0." Effective February 1, 2013.
Operating Days per Year	365	365	The source for this data is unknown.
Operating Hours per Day	12	12	
Market Penetration of Electric Water Heaters (%)	3%	3%	The source for this data is unknown.
Market Penetration of Electric Booster Heaters (%)	95%	95%	The source for this data is unknown.

Electric UEC Inputs – Low-Temperature Door-Type Dishwasher

Parameter	Base Case	Low-Temp Measure Case	Source
Specific heat of Water (Btu/lb/°F)	1	1	
Density of Water (lb/gal)	8.2	8.2	
Inlet water Temperature (°F)	61 °F	61 °F	California Energy Commission (CEC). 2011. "CZ2010 Weather Files.xls."
Setpoint Hot Water Temperature (°F)	140 °F	140 °F	The source for this data is unknown.

Parameter	Base Case	Low-Temp Measure Case	Source
Booster Heater Water Temperature Rise (°F)	40 °F	40 °F	National Sanitation Foundation (NSF). (n.d.) NSF/ANSI 3 - Commercial Warewashing Equipment. "Com Dishwashers NSF Energy Star.xlsx."
Electric Water Heater Energy per Gallon (kWh/gal)	0.208	0.208	Pacific Gas and Electric (PG&E). 2015. "Dishmachine Calcs 02092015.xls."
Electric Booster Heater Energy per Gallon (kWh/gal)	0.101	0.101	
Electric Water Heater Efficiency (%)	95%	95%	California Public Utilities Commission (CPUC), Energy Division. 2013. “Workpaper Disposition for Water Fixtures.” February 22. California Public Utilities Commission (CPUC), Energy Division. "DEER-WaterHeater-Calculator-v1.0.xlsm."
Electric Water Booster Heater Efficiency (%)	95%	95%	
Number of Racks per day (racks/day)	140.5	140.5	Pacific Gas and Electric (PG&E). 2015. "Dishmachine Calcs 02092015.xls." See “Monitored Data + GPR” tab.
Water Consumption (gal/rack)	1.50	0.86	National Sanitation Foundation (NSF). (n.d.) NSF/ANSI 3 - Commercial Warewashing Equipment. "Com Dishwashers NSF Energy Star.xlsx."
Daily Water Consumption (gal)	211	120	Calculated = Racks per Day x Gal/Rack
Daily Booster Consumption (gal)	211	120	Calculated = Racks per Day x Gal/Rack
Wash time per rack (min/rack)	1	1	The source for this data is unknown.
Idle Energy Rate (kW)	0.7	0.7	ENERGY STAR. 2012. “ENERGY STAR Program Requirements for Commercial Dishwashers. Eligibility Criteria (Rev. July 2012) Version 2.0.” Effective February 1, 2013.
Operating Days per Year	365	365	The source for this data is unknown.
Operating Hours per Day	12	12	
Market Penetration of Electric Water Heaters (%)	3%	3%	The source for this data is unknown.
Market Penetration of Electric Booster Heaters (%)	n/a	n/a	-

A sample calculation of annual UEC of a base case high-temperature electric door-type dishwasher in a commercial food service application that uses electric primary water heating is shown below.

$$Electric\ \ Water\ Heater\ Energy = GPR \times RACKS \times EDAYS \times UECGAL \times MktPen$$

$$Electric\ \ Water\ Heater\ Energy = \left(\left(\frac{Gal}{Rack}\right) \times \left(\frac{Racks}{day}\right) \times \left(\frac{Energy}{Gal}\right) + Idle\ Energy\right) \times \frac{day}{yr} \times\ MktPen$$

$$= \left(1.06\ \left(\frac{Gal}{Rack}\right) \times 141\ \left(\frac{Racks}{Day}\right) \times 0.200 \left(\frac{kWh}{Gal}\right) + 6.76 \frac{kWh}{day}\right) \times 365 \frac{day}{yr} \times 0.03 = 401\ kWh$$

$$Electric\ \ Booster\ Heater\ Energy = GPR \times RACKS \times UECGAL \times MktPen$$

$$= 1.06 \left(\frac{Gal}{Rack}\right) \times 51{,}283 \left(\frac{Racks}{Year}\right) \times 0.101 \left(\frac{kWh}{Gal}\right) \times 0.95 \ = 5{,}238\ kWh$$

$$Annual\ Idle\ Energy = EDAYS\ \times \left(EHOURS\ - \frac{TWASH}{MIN}\right) \times\ IDLERATE$$

$$= 365\ \times \left(12\ hours/day - \left(\frac{141\ Racks}{day}\right) x \left(\frac{1\ min}{rack}\right) x \left(\frac{1\ hour}{60\ min}\right)\right) \times\ 0.7kW\ \ =\ 2{,}468\ \ kWh$$

$$= \left(365\frac{day}{yr}\right) \times \left(6.76\frac{kWh}{day}\right)\ \ =\ 2{,}468\ \ kWh$$

$$UEC\_YEAR = 8{,}107\ \ kWh$$

PEAK ELECTRIC DEMAND REDUCTION (KW)

The actual contribution to building peak demand can vary significantly depending on the dishwasher usage pattern in relation to that of other electric equipment in the facility (operating schedule, appliance ON time, etc.).

Average Peak Demand Reduction Calculation

The **average peak demand** (baseline or measure case), or the average demand during the peak period, is a function of the unit energy consumption (UEC), the number of hours during the peak period, and the assumed percent of total usage during the peak period.

$$PeakDemand\ _{avg} = \frac{\left(\frac{UEC\_YEAR}{EDAYS}\right)}{PeakHOURS} \times PeakUsePerc$$

UEC_YEAR =	*Annual unit energy consumption (kWh)*
EDAYS=	*Estimated operating days per year (days)*
PeakHOURS =	*Number of hours in the peak period (hours)*
PeakUsePerc=	*Percent of total usage during peak period (%, decimal)*

The *End-use Water Demand Profile* study conducted by Aquacraft, Inc. for the California Public Utilities Commission (CPUC)[13] documents the hourly hot water demand of seven different restaurants. Analysis of the study data reveals that 39% of total daily energy use occurs during the peak demand period between 4:00 p.m. and 9:00 p.m.[14] Therefore, it is assumed that the probable contribution to building peak demand is equal to the dishwasher average demand during the peak period.

[13] Aquacraft, Inc. 2011. *Embedded Energy in Water Studies. Study 3: End-use Water Demand Profiles.* Prepared for the California Public Utilities Commission. CALMAC Study ID: CPU0052.

[14] California Public Utilities Commission (CPUC). 2018. *Resolution E-4952.* October 11. Op 1.

Peak Demand Reduction

Peak demand reduction is calculated as the difference between baseline and measure case average peak demand multiplied by the coincidence demand factor (CDF).

$$PeakDemandReduction = \left[\left(PeakDemand_{avg,base} - PeakDemand_{avg,measure}\right) \times CDF\right]$$

$PeakDemand_{avg} =$ *Average peak demand, baseline or measure (kW)*

$CDF =$ *Coincident demand factor*

Inputs and Assumptions

The table below provides the inputs for the calculation of peak demand reduction of a commercial door-type dishwasher (high- and low-temperature models).

Demand Reduction Inputs

Parameter	Value	Source
Percent of Total Daily Usage During Peak Period	0.39	Aquacraft, Inc. 2011. *Embedded Energy in Water Studies. Study 3: End-use Water Demand Profiles.* Prepared for the California Public Utilities Commission. CALMAC Study ID: CPU0052.
Number of Hours in Peak Period	3	California Public Utilities Commission (CPUC). 2006. *D 06-06-063 in the Order Instituting Rulemaking to Promote Consistency in Methodology and Input Assumptions in Commission Applications of Short-Run and Long-Run Avoided Costs, Including Pricing for Qualifying Facilities. (R.04-04-025).* June 29.
Coincident Demand Factor (CDF)	0.90	Itron, Inc. 2005. *2004-2005 Database for Energy Efficiency Resources (DEER) Update Study - Final Report.* Prepared for Southern California Edison.

GAS SAVINGS (THERMS)

The basis for gas unit energy savings (UES) is the difference between the water heating unit energy consumption (UEC) of the base case and measure case dishwasher models. Because energy-efficient units require considerably less water, less energy is required for water heating. For both low- and high-temperature machines, the base case UEC is based on the energy required to heat water for the dishwashing and sanitizing cycles. The high-temperature unit water heating energy components are further split into *primary* and *booster* water heating.

The calculation of the annual gas UEC is calculated as the difference between the baseline UEC and the measure case UEC. Note that motor energy and standby losses are assumed to be the same for both the base case and the measure case and are therefore not presented in the energy savings calculations.

$$UEC_{YEAR} = Gas\ Water\ Heater\ Energy + GasBooster\ Water\ Heater\ Energy + Idle\ Energy$$

Each term in the UEC calculation is detailed below, followed by all inputs and assumptions.

Gas Water Heater Energy Use

Water heater energy use is a function of water consumption (GPR), the number of racks washed per year, the UEC per gallon of water, and market penetration of electric water heating and booster heating.

$$Gas\ \ Water\ Heater\ Energy = GPR \times RACKS \times EDAYS \times UECGAL \times MktPen$$

GPR = Water consumption (GPR)
RACKS = Number of racks washed per day (#)
EDAYS = Operating days per year (days)
UECGAL = UEC per gallon of water (Therms)
MktPen = Market penetration of gas water heating (%, decimal)

Water Consumption (GPR). The National Sanitation Foundation (NSF) provides a database of commercial dishwashers that reports manufacturer calculated water consumption in gallons per rack (GPR).[15] The database includes models that meet the ENERGY STAR performance criteria[16] for reduced water consumption (1.18 GPR for low-temperature units, and 0.95 GPR for high-temperature units), even models that qualify but for which the ENERGY STAR label was not pursued. The water and energy consumption calculations for this measure exclude models that are no longer manufactured.

Racks per Year. The number of racks per year is equal to the number of racks per day multiplied by the assumed number of days of operation per year.

Racks per Day. The number of racks per day is based on monitored data from five different restaurant sites (fast casual, fine dining, cafes, and quick service restaurants) and dishwasher leasing companies that track the racks per month as part of the equipment lease agreements. The monitored data was provided by the Food Service Technology Center (FSTC).[17]

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[15] National Sanitation Foundation (NSF). (n.d.) NSF/ANSI 3 - Commercial Warewashing Equipment. "Com Dishwashers NSF Energy Star.xlsx."

[16] ENERGY STAR. 2012. "ENERGY STAR Program Requirements for Commercial Dishwashers. Eligibility Criteria (Rev. July 2012) Version 2.0." Effective February 1, 2013.

[17] Pacific Gas and Electric (PG&E). 2015. "Dishmachine Calcs 02092015.xls."

UEC per Gallon of Water. The UEC per gallon of water is based on the increase in water temperature required for a wash cycle, the specific heat of water, the weight of water, and the heating equipment efficiency.

$$UEC\ per\ Gallon\ (Therm) = \left(\frac{\Delta T \times C \times \rho}{\eta \times}\right) \times \frac{Therm}{Btu}$$

where:

ΔT = *Temperature rise (°F)*

C = *Specific heat of water, the energy required to raise one pound of water by one-degree, constant* $\left(\frac{Btu}{lb-°F}\right)$

ρ = *Density of water, constant* $\left(\frac{lbs}{gal}\right)$

η = *Gas heating equipment efficiency*

$Therm/Btu$ = *Btu to therm conversion factor*

The parameters to calculate the UEC per gallon of water are explained below.

Temperature Rise (°F) – This analysis assumes an average inlet water temperature of 61 °F that needs to be raised to 140 °F to meet the minimum supply water temperature at the dishwasher. The average inlet water temperature is calculated as the average annual ground water temperature across all California climate zones. This water heating requirement applies to both low- and high-temperature machines. For high-temperature machines, there is an extra sanitizing rinse that increases the water temperature via a dishwasher booster water heater an additional 40 °F, to 180 °F to meet the National Sanitation Foundation (NSF) mandated sanitation criteria. (The low-temperature machines meet this standard via a chemical rinse).

Heating Equipment Efficiency (%) – Heating equipment efficiency varies between electric and gas units, as well as between external primary water heating and internal booster heating. The assumptions of water heating equipment efficiency conform to the California Public Utility Commission (CPUC) Energy Division disposition issued in February 2013.[18]

Gas booster heating unit efficiency is used to determine the additional energy consumption of the booster water heating in high temperature units. These engineering assumptions are consistent with those used for ENERGY STAR eligibility.[19]

Gas Booster Water Heater Energy

The methodology to derive the booster gas water heating UEC followed the same methodology to calculate the Gas Water Heater Energy. The booster heater, however, is needed to increase 100% of the water from a temperature of 140 °F to 180 °F.

[18] California Public Utilities Commission (CPUC), Energy Division. 2013. "Workpaper Disposition for Water Fixtures." February 22.

[19] ENERGY STAR. 2012. "ENERGY STAR Program Requirements for Commercial Dishwashers. Eligibility Criteria (Rev. July 2012) Version 2.0." Effective February 1, 2013.

$$Gas\ \ Booster\ Heater\ Energy = GPR \times RACKS \times UECGAL \times MktPen_{gas,booster}$$

GPR = Water consumption (GPR)

RACKS = Number of racks washed per year (#)

UECGAL = UEC per gallon of water (Btu)

MktPen = Market penetration of gas booster water heating (%, decimal)

Note that a low-temperature dishwasher will not have booster heater energy as part of the calculation and this term will equal zero for the low-temperature model.

Market Penetration of Booster Heating Fuel Types. A high-temperature unit achieves energy savings via primary water heating as well as booster water heating. It is assumed that restaurants with electric primary heating will only install electric dishwashers with electric booster heating. While most restaurants with gas primary water heating are more likely to install an electric dishwasher with electric booster heating, gas booster heating is available and is installed in a small percentage of restaurants. The assumed percentages of market penetration for each primary/booster fuel combination are provided below. These percentages were applied to the primary water heating energy savings for low- and high-temperature units.

Market Penetration of Primary Water Heating and Booster Water Heating Fuel Combinations

Primary/Booster Fuel Combination	Penetration (%)	Source
Electric/Electric	3%	The source of this data is unknown.
Gas/Gas	5%	
Gas/Electric	92%	

Annual Idle Energy

Annual idle energy use is a function of operating hours, wash time, idle energy rate, and the market penetration of primary and booster water heating fuel types.

$$Annual\ Idle\ Energy = EDAYS\ \times \left(EHOURS - \frac{TWASH}{MIN}\right) \times\ IDLERATE$$

EDAYS=	*Estimated operating days per year (days)*
EHOUR=	*Estimated operating hours per day (hrs)*
TWASH =	*Estimated wash time per rack (min)*
MIN =	*Constant minutes per hour (min)*
IDLERATE =	*Measured idle energy rate (Btu)*

Operating Hours per Day and **Operating Days per Year.** The commercial dishwasher hours and days per year of operation was derived from an independent survey of 54 food service establishments conducted by Navigant Consulting.[20] The survey sample included independent restaurants, casual concept (big chain) restaurants, and fast food chains. These assumed hours and days of operation align with assumptions for

[20] The source for this data or information is unknown.

many other food service measures drawn from a food service equipment market potential study conducted for the California Energy Commission (CEC) by Fisher-Nickel, Inc.[21]

Idle Energy Rate. The idle energy rate for high-temperature and low-temperature machines is based upon the ENERGY STAR eligibility requirements in the Measure Case Description.

Market Penetration of Booster Heating Fuel Types. See Gas Booster Water Heater Energy.

Annual Gas Unit Energy Savings

The **annual UES** is calculated as the difference between the baseline and measure case annual UEC.

$$UES\_YEAR = [UEC\_YEAR_{Base} - UEC\_YEAR_{Measure}]$$

Inputs and Assumptions

The inputs for the calculation of the annual gas UEC for both low- and high-temperature door-type units are specified below.

Gas UEC Inputs – High-Temperature Door-Type Dishwasher

Parameter	Base Case	High-Temp Measure Case	Source
Specific heat of Water (Btu/lb/°F)	1	1	
Density of Water (lb/gal)	8.2	8.2	
Inlet water Temperature (°F)	61 °F	61 °F	California Energy Commission (CEC). 2011. "CZ2010 Weather Files.xls."
Setpoint Hot Water Temperature (°F)	140 °F	140 °F	The source for this data is unknown.
Booster Heater Water Temperature Rise (°F)	40 °F	40 °F	National Sanitation Foundation (NSF). (n.d.) NSF/ANSI 3 - Commercial Warewashing Equipment. "Com Dishwashers NSF Energy Star.xlsx."
Gas Water Heater Energy per Gallon (therms/gal)	0.0087	0.0087	Pacific Gas and Electric (PG&E). 2015. "Dishmachine Calcs 02092015.xls."
Gas Booster Heater Energy per Gallon (therms/gal)	0.0043	0.0043	
Gas Water Heater Efficiency (%)	95%	95%	California Public Utilities Commission (CPUC), Energy Division. 2013. "Workpaper Disposition for Water Fixtures." February 22. California Public Utilities Commission (CPUC), Energy Division. "DEER-WaterHeater-Calculator-v1.0.xlsm."
Gas Water Booster Heater Efficiency (%)	95%	95%	
Number of Racks per day (racks/day)	140.5	140.5	Pacific Gas and Electric (PG&E). 2015. "Dishmachine Calcs 02092015.xls." See "Monitored Data + GPR" tab.

[21] Spoor, C., D. Zabrowski, and L. Mills. (Fisher-Nickel, Inc.) 2014. *Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Food Service Equipment.* Prepared for the California Energy Commission. CEC-500-2014-095.

Parameter	Base Case	High-Temp Measure Case	Source
Water Consumption (Gal/Rack)	1.06	0.60	National Sanitation Foundation (NSF). (n.d.) NSF/ANSI 3 - Commercial Warewashing Equipment. "Com Dishwashers NSF Energy Star.xlsx."
Daily Water Consumption (Gal)	149	84	Calculated = Racks per Day x Gal/Rack
Daily Booster Consumption (Gal)	149	84	Calculated = Racks per Day x Gal/Rack
Wash time per rack (min/rack)	1	1	The source for this data is unknown.
Idle Energy Rate (Btu/hr))	0	0	-
Operating Days/Year	365	365	The source for this data is unknown.
Operating Hours/Day	12	12	
Market Penetration of Gas Water Heaters (%)	97%	97%	The source for this data is unknown.
Market Penetration of Gas Booster Heaters (%)	5%	5%	The source for this data is unknown.

Gas UEC Inputs – Low-Temperature Door-Type Dishwasher

Parameter	Base Case	High-Temp Measure Case	Source
Specific heat of Water (Btu/lb/°F)	1	1	
Density of Water (lb/gal)	8.2	8.2	
Inlet water Temperature (°F)	61 °F	61 °F	California Energy Commission (CEC). 2011. “CZ2010 Weather Files.xls.”
Setpoint Hot Water Temperature (°F)	140 °F	140 °F	The source for this data is unknown.
Booster Heater Water Temperature Rise (°F)	40 °F	40 °F	National Sanitation Foundation (NSF). (n.d.) NSF/ANSI 3 - Commercial Warewashing Equipment. "Com Dishwashers NSF Energy Star.xlsx."
Gas Water Heater Energy per Gallon (therms/gal)	0.0087	0.0087	Pacific Gas and Electric (PG&E). 2015. "Dishmachine Calcs 02092015.xls."
Gas Booster Heater Energy per Gallon (therms/gal)	0.0043	0.0043	
Gas Water Heater Efficiency (%)	95%	95%	California Public Utilities Commission (CPUC), Energy Division. 2013. “Workpaper Disposition for Water Fixtures.” February 22. California Public Utilities Commission (CPUC), Energy Division. "DEER-WaterHeater-Calculator-v1.0.xlsm."
Gas Water Booster Heater Efficiency (%)	n/a	n/a	
Number of Racks per day (racks/day)	140.5	140.5	Pacific Gas and Electric (PG&E). 2015. "Dishmachine Calcs 02092015.xls." See “Monitored Data + GPR” tab.
Water Consumption (Gal/Rack)	1.06	0.60	National Sanitation Foundation (NSF). (n.d.) NSF/ANSI 3 - Commercial Warewashing Equipment. "Com Dishwashers NSF Energy Star.xlsx."
Daily Water Consumption (Gal)	149	84	Calculated = Racks per Day x Gal/Rack
Daily Booster Consumption (Gal)	149	84	Calculated = Racks per Day x Gal/Rack

Parameter	Base Case	High-Temp Measure Case	Source
Wash time per rack (min/rack)	1	1	The source for this data is unknown.
Idle Energy Rate (therms)	0	0	-
Operating Days/Year	365	365	The source for this data is unknown.
Operating Hours/Day	12	12	
Market Penetration of Gas Water Heaters (%)	97%	97%	The source for this data is unknown.
Market Penetration of Gas Booster Heaters (%)	n/a	n/a	-

The sample calculation below is for a high-temperature, gas-fueled, door-type dishwasher in a commercial food service application that uses a gas primary water heater. Low-temperature dishwashers will not have booster heater energy as part of the calculation and is set to zero.

$$Annual\ Gas\ \ Water\ Heater\ Energy = GPR \times RACKS \times EDAYS \times UECGAL \times MktPen$$

$$= 1.06\left(\frac{Gal}{Rack}\right) \times 51{,}283\left(\frac{Racks}{Year}\right) \times 0.0087\left(\frac{Therms}{Gal}\right) \times 0.97 = 459\ Therms$$

$$Annual\ Gas\ \ Booster\ Heater\ Energy = GPR \times RACKS \times UECGAL \times MktPen$$

$$= 1.06\ \left(\frac{Gal}{Rack}\right) \times 51{,}283\left(\frac{Racks}{Year}\right) \times 0.0043\ \left(\frac{Therms}{Gal}\right) \times 0.05 = 12\ Therms$$

$$Annual\ Idle\ Energy = EDAYS\ \times \left(EHOURS\ - \frac{TWASH}{MIN}\right) \times\ IDLERATE$$

$$= 365\ \times \left(12\ hours - \left(\frac{141\ Racks}{day}\right) x \left(\frac{1\ min}{rack}\right) x \left(\frac{1\ hour}{60\ min}\right)\right) \times\ 0\frac{Btu}{hr} =\ 0\ Therms$$

$$UEC\_YEAR = 471\ Therms$$

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.

As shown below, the EUL specified for both low- and high-temperature dishwasher models is equal to the ENERGY STAR typical product EUL for door-type units. Note that RUL is only applicable for add-on and accelerated replacement measures and not applicable for this measure.

Effective Useful Life and Remaining Useful Life

Parameter	Value	Source
EUL (yrs)	15	ENERGY STAR. 2013. "Savings Calculator for ENERGY STAR Certified Commercial Equipment." "commercial_kitchen_equipment_calculator.xls." Last updated February 2013. See "Assumptions" tab.
RUL (yrs)	n/a	n/a

BASE CASE MATERIAL COST ($/UNIT)

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

For *all other delivery types*, the base case material cost was calculated as the average unit cost of base case low-temperature and high-temperature commercial dishwasher models.[22] Unit costs were obtained from various sources including the AutoQuotes online catalog, equipment sales reps, and manufacturer sources. Since food service equipment pricing in competitively sensitive information and prices vary widely according to buying volume and other factors, the sources for prices are not publicly available.

MEASURE CASE MATERIAL COST ($/UNIT)

The measure case material costs for *all delivery types* were calculated as the average unit cost base case low-temperature and high-temperature commercial dishwasher models.[23] Unit costs were obtained from various sources including the AutoQuotes online catalog, equipment sales reps, and manufacturer sources. Since food service equipment pricing in competitively sensitive information and prices vary widely according to buying volume and other factors, the sources for prices are not publicly available.

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*, the base case and measure case model installation costs are expected to be the same for the customer and thus not estimated for the incremental cost analysis.

MEASURE CASE LABOR COST ($/UNIT)

The measure case labor cost for equipment *delivered via direct install* will be derived as the average installation cost submitted by one or more implementation contractors. The actual installation cost can vary by contractor, the date when the work occurred, and by the volume of each specific contractor's business. Contractor costs are confidential information and are based upon contractually agreed upon pricing as established in their purchase order with the program administrator. Therefore, the program administrator program tracking systems are the only source for the labor installation cost data. The

[22] Pacific Gas and Electric (PG&E). 2015. "Dishmachine Calcs 09092015.xls."

[23] Pacific Gas and Electric (PG&E). 2015. "Dishmachine Calcs 09092015.xls."

program administrator will utilize the actual program cost to evaluate the cost-effectiveness of the measure.

For *all other delivery types*, a high efficiency model does not require additional installation labor compared to a base case model. Since this measure is applicable for normal replacement and new construction installations, the base case and measure case model installation costs are expected to be the same for the customer and thus not estimated for the incremental cost analysis.

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.
NTG – Industrial	0.60	
NTG - Agriculture	0.60	

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

Water savings is the primary non-energy impact associated with high efficiency commercial dishwashers. The calculation of annual water savings of an energy efficient (measure case) commercial dishwasher is calculated as the difference between the baseline and measure annual water consumption. The inputs for this calculation are specified in Electric Savings.

$$UWC = GPR \times RACKS \times EDAYS$$

$GPR = Water\ consumption\ (GPR)$
$RACKS = Number\ of\ racks\ washed\ per\ day\ (\#)$
$EDAYS = Operating\ days\ per\ year\ (days)$

$$UWS = UWC_{Base} - UWC_{Measure}$$

$UWC = Annual\ unit\ water\ consumption\ (gal\ per\ year)$
$UWS = Annual\ unit\ water\ savings\ (gal\ per\ year)$

DEER DIFFERENCES ANALYSIS

The table below summarizes the inputs and methods that are and are not based upon the Database for Energy Efficient Resources (DEER).

DEER Difference Summary

DEER Item	Comment / Used for Workpaper
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	n/a – Applicable to all restaurant and kitchen facilities
DEER Version	None
Reason for Deviation from DEER	DEER 2014 does not contain information on energy use or savings or equipment costs for an energy-efficient commercial dishwasher.
DEER Measure IDs Used	n/a
NTG	Source: DEER. NTG of 0.60 is associated with NTG ID: *Com-Default>2yrs*, *Ag-Default>2yrs*, *Ind-Default>2yrs*
GSIA	Source: DEER. The value of 1.0 is associated with GSIA ID: *Def-GSIA*
EUL/RUL	Source: ENERGY STAR. The value of 15 years is associated with EUL ID: *Appl-DW-Dtu*

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Revision Complete Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision
01	07/31/2017	Jennifer Holmes Cal TF Staff	Draft of consolidated text for this statewide measure is based upon: PGECOFST126, Revision 0 (July 1, 2016) Consensus reached among Cal TF members.
	10/11/2018 10/30/2018	Jennifer Holmes Cal TF Staff	Completed final revisions for submittal of version 01.
	7/1/2019	Ayad Al-Shaikh Cal TF Staff	Updated delivery type IDs.