California Air Resources Board

Greenhouse Gas Quantification Methodology for the Department of Water Resources Water-Energy Grant Program

Greenhouse Gas Reduction Fund FY 2015-16

Updated*
September 28, 2016

*The quantification methodology has been updated with screenshot figures to reflect the accompanying greenhouse gas emission reduction calculator. The greenhouse gas emission reduction calculator has been updated to automate calculations for total project cost. No changes have been made to the methods or equations.

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Section A. Introduction

The California Air Resources Board (ARB) is responsible for providing the quantification methodology to estimate greenhouse gas (GHG) emission reductions from projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF) for California Climate Investments. For the California Department of Water Resources (DWR) Water-Energy Grant Program, ARB staff developed this GHG emission reduction quantification methodology and the accompanying ARB GHG Calculator tool to be used by applicants to estimate proposed project GHG emission reductions, energy savings, and water savings. ARB staff will periodically review each quantification methodology to evaluate its effectiveness and update methodologies to make them more robust, user-friendly, and appropriate to the projects being quantified.

This methodology uses calculations to estimate the GHG emission reductions associated with energy savings and estimates water savings from commercial, institutional, and residential project measures, such as replacing equipment with Energy Star products. The estimates are calculated using commercially available energy-efficient equipment specifications compared to conventional or pre-existing[1] equipment specifications.

ARB released the initial draft and revised draft quantification methodology and ARB GHG Calculator tool for public comment in April 2016 and July 2016, respectively. This FY 2015-16 quantification methodology and accompanying GHG emission reduction calculator have been updated to reflect DWR Program updates and public input received.

Methodology Development

ARB staff followed a set of principles to guide the development of the quantification methodology. These principles ensure that the methodology for the Water-Energy Grant Program projects will:

- Apply at the project-level.
- Align with the project measures proposed for funding.
- Provide uniform methodologies that can be applied statewide, and be accessible by all applicants.
- Estimate GHG emission reductions from the proposed project measures.
- Use existing and proven tools or methodologies where available.
- Use project-level data, when available, for estimated energy use reductions.

The methodology fits these objectives, and provides a uniform approach to quantify GHG emission reductions in metric tons of carbon dioxide equivalent ($MTCO_2e$).

[1] Conventional refers to the federally used, default specifications adopted from the Energy Star Commercial Kitchen Equipment Calculator and Energy Star Qualified Appliance Calculator, developed by the Environmental Protection Agency (EPA) and the Department of Energy (DOE). Pre-existing equipment specifications may pre-date conventional equipment and may not match the provided defaults.

Eligible Water-Energy Grant Program Projects

Commercial and institutional facility types,[2] as well as residential projects benefiting disadvantaged communities, are eligible for the 2016 Water-Energy Grant Program.

Per Water-Energy Grant Program Guidelines,[3] eligible project measures must:

- Reduce GHG emissions through reduced energy use.
- Reduce water use.

Note: Projects that reduce water consumption, but do not reduce energy use, or vice-versa, are not eligible and cannot be quantified using this methodology.

Tools

Applicants must use the ARB GHG Calculator tool, located at http://www.arb.ca.gov/cc/capandtrade/auctionproceeds/quantification.htm to estimate the GHG emission reductions from their proposed 2016 Water-Energy Grant Program project measures. GHG emission reductions result from the installation of energy efficient measures, such as appliances and fixtures.

The ARB GHG Calculator tool adopted methodologies from the Energy Star Commercial Kitchen Equipment Calculator and Energy Star Qualified Appliance Calculator, developed by the Environmental Protection Agency (EPA) and the Department of Energy (DOE), to estimate energy savings and water savings for certified Energy Star products for project measures that are eligible through DWR's 2016 Water-Energy Grant Program. Additional methodologies for faucets and showerheads were developed to expand the capabilities of the ARB GHG Calculator tool. Modifications to the Energy Star calculators were made to accommodate the 2016 Water-Energy Grant Program objectives and to provide consistency with other ARB approved quantification materials. The modifications included structural adjustments, incorporation of California Climate Zone water heater inlet temperatures, California average grid electricity emission factor, and other changes that are referenced throughout the ARB GHG Calculator tool.

This quantification methodology and accompanying ARB GHG Calculator tool estimates GHG emission reductions associated with direct, on-site energy savings. This ARB quantification methodology and calculator must be used to estimate GHG emission reductions for DWR's 2016 Water-Energy Grant Program. As part of the public comment period, ARB received a number of requests to also include other indirect energy considerations associated with water conservation, such as the energy savings

[2] "Facility type" is defined as a building designated for a particular use or purpose. Different buildings can be of the same facility type. For example, multiple hotel buildings are considered the same facility type, whereas a hotel and a restaurant are two separate facility types.
[3] DWR Water-Energy Grant Program Guidelines are accessed through DWR's Water-Energy Grant Program website at: http://www.water.ca.gov/waterenergygrant/index.cfm.

estimated by the Water Energy Cost Effectiveness Calculator[4] adopted by the California Public Utilities Commission (CPUC) in fall 2015 (updated February 2016). The CPUC Water Energy Cost Effectiveness Calculator is available as another informational tool for applicants to estimate indirect energy savings, but is not required to estimate GHG emission reductions for the DWR 2016 Water-Energy Grant Program. While a useful tool, the CPUC calculator was designed to estimate the avoided cost of indirect energy used to pump, convey, treat, and distribute cold water, but not GHG emission reductions. Furthermore, the CPUC calculator is intended for use by commission-jurisdictional water utilities and energy efficiency Program Administrators, which does not align perfectly wi.th the eligible participants for DWR's 2016 Water-Energy Grant Program.

GHG Emission Reductions Quantification Approach

The metric used to evaluate the effectiveness of the project measure(s) to reduce GHG emissions per dollar of GGRF funds will be reported by the applicant as:

$$\frac{Total\ Project\ GHG\ Reductions\ (Metric\ Tons\ of\ CO_2e)}{Total\ GGRF\ Funds\ Requested\ (\$)}$$

Total GGRF Funds Requested is the dollar amount requested through the Water-Energy Grant Program and any other GGRF programs to which the applicant has applied or may apply. The ARB GHG Calculator tool estimates GHG emission reductions per Total Project Cost, and also estimates water savings. These metrics are used by DWR as project selection criteria, as outlined in DWR's 2016 Water-Energy Grant Program Guidelines and solicitation materials. Additional documentation and reporting requirements are provided in Sections C and D.

Requirements for Program implementation and reporting are subject to change based on future revisions that apply to the Program (e.g., legislation, updates to ARB's Funding Guidelines). Implementing agencies/grantees should note that additional reporting may be required or modified for some types of projects based on the evolving needs of the Program. For example, the requirements and methods of data collection are still under development for Phase 2 reporting and will be published at a later date.

The following sections describe the process for estimating the GHG emission reductions for proposed projects in the 2016 DWR Water-Energy Grant Program.

[4] The CPUC Water Energy Cost Effectiveness Calculator is available on the CPUC Water/Energy Nexus website at: http://www.cpuc.ca.gov/nexus_calculator/.

Program Assistance

DWR will establish a technical review team to review the quantification portions of the 2016 Water-Energy Grant Program project applications to ensure that the methods described in this document were properly applied to estimate GHG emission reductions associated with energy savings, and water savings for the proposed project measure(s). Applicants should use the following resources for additional questions and comments:

- Questions on this document should be sent to GGRFProgram@arb.ca.gov.
- For more information on ARB's efforts to support implementation of GGRF investments, see: www.arb.ca.gov/auctionproceeds.
- Questions pertaining to the Water-Energy Grant Program should be sent to DWR_IRWM@water.ca.gov.

Section B. Quantification Methodology

This methodology estimates GHG emission reductions associated with energy savings for the proposed 2016 Water-Energy Grant Program project measures. Additionally, this methodology estimates water savings from proposed project measures for DWR evaluation purposes. Energy savings are the result of increased energy efficiency and/or reduced hot water usage, which reduces electricity and/or thermal energy consumption. Applicants must use the ARB GHG Calculator tool to estimate the annual and project total GHG emission reductions associated with energy savings from each project measure over the estimated equipment life,[5] as defined in this methodology. Due to DWR Program requirements, water savings are also estimated using the ARB GHG Calculator tool.

The following is a summary of the steps the 2016 Water-Energy Grant Program applicants will follow to estimate and report the GHG emission reductions, energy savings, and water savings for a proposed project measure. Detailed instructions for each step are provided on subsequent pages. An example of a proposed 2016 Water-Energy Grant Program project quantification is included in Appendix A.

Step 1 **Identify the Proposed Project Measure(s)**: The applicant must select at least one project measure as identified in Table 1 of this document. If a measure is not listed, it is not eligible for funding in the 2016 Water-Energy Grant Program.

Step 2 **Estimate GHG Emission, Energy Savings, and Water Savings**: The applicant will enter the project details into the ARB GHG Calculator tool to estimate GHG emission reductions, energy savings, and water savings for each project measure.

[5] The estimated equipment life for each project measure will vary.

Step 1: Identify the Proposed Project Measure(s)

Table 1 identifies the project measures that are eligible for funding under the 2016 Water-Energy Grant Program.

Table 1. Eligible Project Measures

Commercial/Institutional Facilities, and Residential Projects Benefiting Disadvantaged Communities	Data Required[6]
Commercial Dishwasher	Number of units, racks washed per day, water heater fuel type, booster water heater fuel type (if applicable), and operating days per year.
Residential Dishwasher	Number of units, type of dishwasher, number of cycles per week, water heater fuel type, rated electricity consumption, and rated water consumption.
Commercial Clothes Washer	Number of units, washer load configuration, average number of loads per week, water heater fuel type, washer capacity, modified energy factor (MEF), water factor (WF), and dryer fuel type.
Residential Clothes Washer (Single- and Multi-Family[7])	Number of units, configuration, number of loads per week, water heater fuel type, capacity, integrated modified energy factor (IMEF or MEF), integrated water factor (IWF or WF), and dryer fuel type.
Commercial Ice Machine	Number of units, harvest rate, potable water use per 100 pounds of ice, and operating days per year.
Commercial Steam Cooker	Number of units, pounds of food cooked per day per unit, number of pans per unit, operating hours per day, and operating days per year.
Commercial Combination Oven	Number of units, pounds of food cooked per day per unit, number of pans per unit, operating hours per day, and operating days per year.

[6] Additional information will be required, as necessary and appropriate, to substantiate inputs. See Section C of the quantification methodology for more detail on the documentation requirements.
[7] For residential clothes washers in multi-family buildings, the default values in the ARB GHG Calculator tool are based on commercial clothes washer specifications.

Commercial/Institutional Facilities, and Residential Projects Benefiting Disadvantaged Communities	Data Required[6]
Commercial Pre-Rinse Spray Valve	Number of units, flow rate, operating minutes per day, percentage of hot water used for rinse, and water heater fuel type.
Commercial/Residential Faucet[8]	Number of units, flow rate, minutes used per day, percentage of hot water used, water heater fuel type, number of employees per day (if applicable), and number of guests per day (if applicable).
Commercial/Residential Showerhead	Number of units, flow rate, minutes used per day, percentage of hot water used, water heater fuel type, and number of employees per day (if applicable).

[8] Commercial faucet use is assumed for unrestricted public use by multiple individuals (i.e., employees and guests). Commercial shower use is assumed for employee use only. An employee is defined as a person who works for another person or for a company for wages or a salary; A guest is defined as a person who pays for the services of an establishment (as a hotel or restaurant) ("Employee" and "Guest." Merriam-Webster.com, 2015. http://www.merriam-webster.com/).

By default, the ARB GHG Calculator tool assumes guest faucet and shower usage for public restrooms (i.e., 50% of guests use faucets and 0% of guests use showers). If these defaults are not appropriate for a proposed project (such as for a hotel facility), they can be modified to more project-specific values in the corresponding "Com. Faucet Calcs" and "Com. Showerhead Calcs" tabs of the ARB GHG Calculator tool. Recommended default values for hotel guest faucet and showerhead usage can be found in the EPA WaterSense's WaterUSE Tool (Version 1.2) available on the WaterSense webpage at: https://www3.epa.gov/watersense/commercial/challenge_tools.html.

Step 2: Estimate GHG Emission Reductions, Energy Savings, and Water Savings Using the ARB GHG Calculator Tool (Attachment 2a from Water-Energy Grant Program Guidelines)

Applicants must use the Excel-based ARB GHG Calculator tool located at http://www.arb.ca.gov/cc/capandtrade/auctionproceeds/quantification.htm to estimate the GHG emission reductions, energy savings, and water savings from their proposed 2016 Water-Energy Grant Program project measures. The following provides an overview of the ARB GHG Calculator tool.

GHG Emission Reduction Calculations

All equations and calculations are included in the ARB GHG Calculator tool and are located in the respective calculations tabs for each proposed project measure. A summary of GHG emission reductions, energy savings, and water savings are located in the “Results Summary” tab. Detailed equations of the calculations used in the ARB GHG Calculator tool are included in Appendix B of this document. In general, GHG emission reductions, energy savings, and water savings are calculated using the following approaches:

GHG Emission Reductions
$GHG\ Emission\ Reductions = (Electricity\ Savings\ x\ Electricity\ Emission\ Factor) + (Natural\ Gas\ Savings\ x\ Natural\ Gas\ Emission\ Factor)$
Energy Savings
$Energy\ Savings^{9} = Conventional\ Measure\ Energy\ Consumption\ - New\ Measure\ Energy\ Consumption$
Water Savings
$Water\ Savings = Conventional\ Measure\ Water\ Consumption - New\ Measure\ Water\ Consumption$

Read Me Tab

In the table on the “Read Me” tab (as shown on the next page), enter the Project Name and the contact information for the person who can answer project-specific questions from staff reviewers on the quantification calculations. This file will be submitted with other required documents to DWR. For submittals to DWR, please use the following file

[9] Energy savings consists of both electricity and natural gas.

naming convention: “Att2_WE16_Agency_WEGHG-A_#ofTotal#”. For submittals to ARB, DWR will use the following file naming convention: “[Project ID]_[Project Name]” (not to exceed 20 characters). Applicants should not use the latter naming convention for submittals to DWR.

Project Name:	
Project ID:	***To be completed by DWR***
Contact Name:	
Contact Phone Number:	
Contact Email:	
Date Completed:	
Total Water-Energy Grant Funds Requested ($):	**$ -**
Total GGRF Funds Requested, including DWR Water-Energy Grant Funds ($):	**$ -**
Total Cost Share Funds ($)	**$ -**
Total Project Cost ($):	**$ -**

Inputs Tabs

The “Inputs” tabs are dedicated for proposed project measure data and assumptions. Column headers in red font indicate a field that requires an input by the project applicant and the yellow cells indicate fields that can be modified by the project applicant. Each applicant will enter project-measure-specific data into the corresponding yellow cell. Each yellow cell is pre-populated with default values and assumptions. By default, the calculator pre-populates the cells to have no measures installed. If the defaults are not applicable to the project, the user should modify the value to reflect actual number of units, specifications, and/or usage. For example, if an applicant is proposing to install 50 under-counter dishwashers that are high temperature, the applicant can modify the default values for the project measure and provide backup documentation for the appropriate “Quantity” of units, number of “Racks washed per day”, “Building water heater fuel type”, “Booster water heater fuel type”, and “Operating days per year” and other data required (see Table 1).

For proposals that include installation of multiple project measures of the same type, but have different operational usage data, the applicant will enter the information for each applicable project measure in a separate inputs tab. The ARB GHG Calculator tool includes two additional inputs tabs. Inputs must be substantiated in the documentation provided in accordance with Section C on documentation.

Calcs Tab

The “Calcs” tabs (i.e., calculations tabs) are designed to allow applicants to modify data and assumptions for pre-existing and proposed project measure(s). There is a specific “Calcs” tab for each project measure consistent with Table 1. The modifiable fields in the “Calcs” tabs expand on the modifiable fields in the “Inputs” tab to allow for more detailed equipment specification and assumption modifications. For each “Calcs” tab, the yellow cells indicate modifiable assumptions related to the pre-existing measure, proposed measure, and the facility type. The applicant can modify the default values for the project measure, but must provide accompanying backup documentation for each modified assumption.

In the ARB GHG Calculator tool, there is a dedicated “Calcs” tab for each proposed Commercial/Institutional and Residential project measure. The project measures within the calculation tab display a corresponding number (e.g., “(1)”) to refer to the corresponding “Inputs” tab. In each calculations tab, the user can modify the default assumptions (if known) for the conventional or pre-existing measure, new project measure data that is not included in the “Inputs” tab, and/or water-heater-related information, such as efficiency and temperature increase. The default values assume conventional or pre-existing unit specifications based on existing Federal or California standards and/or applicable studies that pertain to each measure where appropriate.

The calculation tabs also provide the project measure(s) energy consumption, water consumption, and savings calculations per project measure. At the bottom of each calculation tab is a “References” section which provides the references for the pre-populated default assumptions.

Summary Tabs

There are two summary tabs—Results Summary and Program Summary.

- The “Results Summary” tab identifies the annual and project total GHG emission reductions, energy savings, and water savings per project measure.
- The “Program Summary” tab provides the project reporting metrics and includes a summary of the overall project reductions.

All values provided in the summary tabs are calculated based on the assumptions provided in the “Input” tabs and the accompanying “Calcs” tabs.

Section C. Documentation (Attachment 2b from Water-Energy Grant Program Guidelines)

Applicants must report the Total Project GHG Emission Reductions, among other results, estimated in the ARB GHG Calculator tool. Applicants are required to provide electronic documentation that is complete and sufficient to allow the calculations to be reviewed and replicated. Paper copies of supporting materials must be available upon request by DWR or ARB staff.

The ARB GHG Calculator tool is configured to calculate GHG emission reductions, energy savings, and water savings from a single facility. The ARB GHG Calculator tool is also configured to calculate estimates for a single facility type for applicants proposing to fund the same project measure(s) across multiple facilities. For example, if the applicant proposes to fund multiple restaurants with the same project measure(s), a single run of the ARB GHG Calculator tool is sufficient for the application. However, if a single project application involves multiple different facility types (such as a restaurant *and* a hotel), a separate run of the ARB GHG Calculator tool is required for each facility type—saved as a separate file per the naming convention described in Step 2 of Section B. The three potential scenarios for application proposals are summarized as follows:

Proposed Facility(ies)	**Number of *Separate* ARB GHG Calculator Tool Runs Required**
Single facility	1
Multiple facilities of the same facility type	1
Multiple facilities of different facility types	Multiple (one for each facility type)

The applicant will submit all of the required documentation and any additional runs of the ARB GHG Calculator tool (if applicable) together. For proposals that include installation of multiple project measures of the same type but have different operational usage data, the applicant will enter the information for each applicable project measure into a separate “inputs” tab.

The following checklist is provided as a guide to applicants; additional data and/or information may be necessary to support project-specific input assumptions.

	Document Description	**Completed**
1.	Project application	
2.	Contact information for the person who can answer project specific questions.	
3.	Populated ARB GHG Calculator tool, submitted as a standalone file (saved as a ".xlsm" or "Excel Macro-Enabled Workbook" file type) for each facility or facility type.	
4.	Project description, including excerpts or specific references to the location in the main Water-Energy Grant Program application of the project information necessary to complete the applicable portions of the quantification methodology.	
5.	If the Total GGRF funds requested are different than the DWR Water-Energy Grant Program GGRF funds requested, provide an explanation of the other GGRF program(s) where funding is sought, including the fiscal year of the application(s).	
6.	Any other information as necessary and appropriate to substantiate inputs (including documentation of the project data and assumptions, and references to public documents used as sources for project data). DWR Guidelines require applicants to provide backup documentation for all input values for the proposed project. This includes ARB GHG Calculator tool default values, even if they are unaltered.	

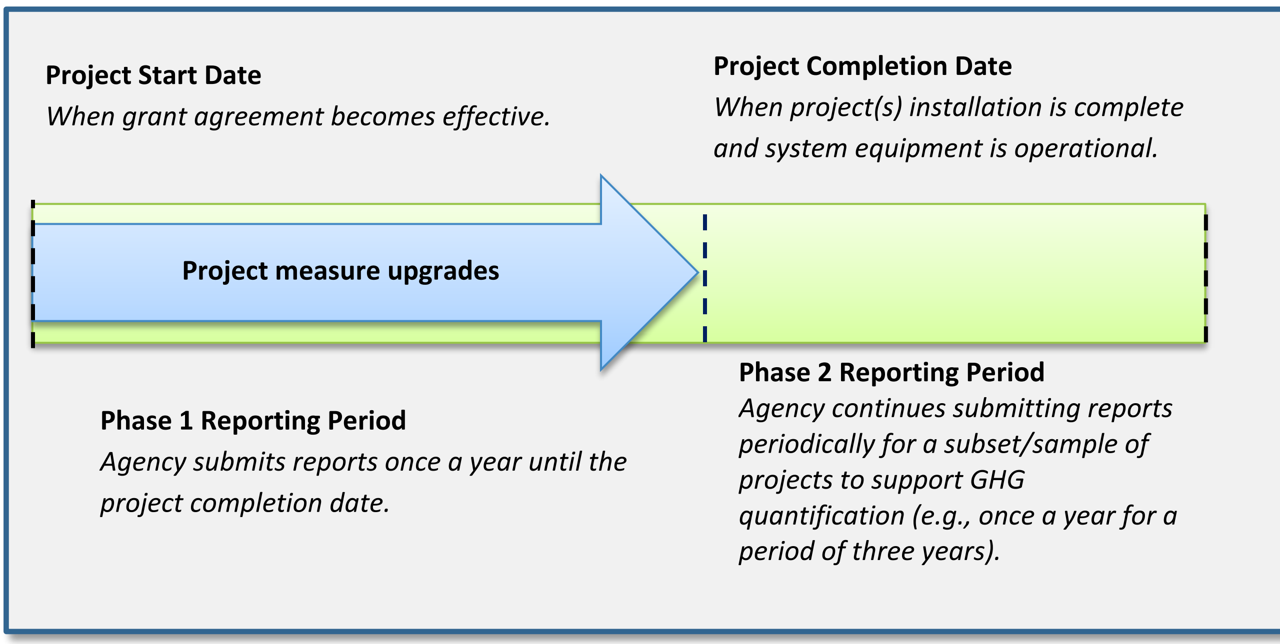
Section D. Reporting after Funding Award

Accountability and transparency are essential elements for all projects funded by the GGRF. Each administering agency is required to track and report on the benefits of the California Climate Investments funded under their program(s) and each funding recipient has the obligation to provide the necessary data or access to data for their project to support reporting on project outcomes.

In 2015, ARB developed Funding Guidelines for Agencies Administering California Climate Investments (Funding Guidelines).[10] These Funding Guidelines describe the reporting requirements and set the minimum project-level reporting requirements for projects funded. Volume 3 of the Funding Guidelines summarizes the major reporting components that DWR must report to ARB. Because much of this data will be aggregated by DWR staff, Water-Energy Grant Program funding recipients will need to provide project data to DWR to support these reporting requirements.

Figure 1 and Table 2 below show the project phases and when reporting is required.

Figure 1. Project Phases and Reporting Periods



[10] California Air Resources Board. Funding Guidelines for Agencies Administering California Climate Investments. December 21, 2015. http://www.arb.ca.gov/cc/capandtrade/auctionproceeds/arb-funding-guidelines-for-ca-climate-investments.pdf.

Table 2. Quantification and Reporting By Project Phase

	Timeframe	Quantification Methodology Section
Project Selection	Covers the period from solicitation to selection of projects and funding awards	All applicants use methods in this QM to **estimate** GHG reductions based on application data.
Phase 1	Covers the period from the beginning of the project until it becomes operational or the initial implementation is completed	Funded projects use methods in this QM, as needed, to update GHG **estimates** based on project changes.
Phase 2	Starts after Phase 1 is complete and a project becomes operational	GHG reductions **achieved** are quantified and reported for a subset of funded projects.

Phase 1 reporting is required for all Water-Energy Grant Program projects. DWR will collect and submit data to ARB to satisfy Phase 1 reporting requirements. Recipients of Water-Energy Grant Program funding must report any changes that impact GHG emission reduction estimates (i.e., assumptions or quantities) to DWR prior to project completion.

Phase 2 reporting is required for only a subset of Water-Energy Grant Program projects and is intended to document actual project benefits achieved after the project becomes operational. Phase 2 data collection and reporting will not be required for every project. DWR will be responsible for identifying the subset of individual projects that must complete Phase 2 reporting, identifying who will be responsible for collecting Phase 2 data, and for reporting the required information to ARB. ARB will work with DWR to address “Phase 2” procedures, including but not limited to:

- The **timelines** for Phase 2 reporting, i.e., when does Phase 2 reporting begin, how long will Phase 2 reporting be needed.
- As applicable, **approaches for determining the subset of projects** that need Phase 2 reporting (i.e., how many **X** projects out of **Y** total projects are required to have Phase 2 reporting).
- **Methods for monitoring or measuring** the necessary data to quantify and document achieved GHG reductions and other select project benefits.
- **Data to be collected**, including data field needed to support quantification of GHG emission benefits.
- Reporting requirements for transmitting the data to ARB or DWR for program transparency and use in reports.

Once the Phase 2 quantification method and data needs are determined, ARB will develop and post the final ARB approved Phase 2 methodology for use in Phase 2 reporting.

Appendix A. Example Project

Introduction

The following is a hypothetical project[11] to demonstrate how the FY 2016 Water-Energy Grant Program would be applied and how to use the ARB GHG Calculator tool to estimate the associated GHG emission reductions, energy savings, and water savings. This example does not provide examples of the supporting documentation that is required of actual project applicants.

Overview of the proposed project

The California Water Agency proposes to install 8 commercial dishwashers, 10 commercial clothes washers, 50 commercial ice machines, 10 commercial steam cookers, 5 commercial combination ovens, and 10 commercial pre-rinse spray valves in multiple hotel facilities. The proposed project will achieve GHG emission reductions from energy savings, as well as water savings by installing more efficient equipment appliances and fixtures. The California Water Agency requested $500,000 in Water-Energy Grant funds. Neither additional GGRF funds from other programs nor additional cost share funds were requested. The project is estimated to have a total project cost of $500,000. For brevity, only inputs and calculations for dishwashers are shown, while the “Results Summary” and “Program Summary” represent associated reductions resulting from the summation of all of the aforementioned measures.

Step 1. Identify the Proposed Project Measure(s)

The applicant’s first step is to identify applicable project measures that will reduce both energy and water usage. DWR provided a list of eligible measures in the 2016 Water-Energy Grant Program guidelines. In addition, Table 1 of this document also provides a list of eligible project measures. Multiple project measures can be combined for a single facility type (e.g., supermarket or restaurant). For proposals that include installation of multiple project measures of the same type but have different operational usage data due to facility type, the applicant will enter the information for each applicable project measure into a separate “inputs” tab.

[11] The hypothetical project has not undergone verification of any DWR Water-Energy Grant Program requirements; all assumptions about location type and features are for quantification methodology demonstration purposes only.

Step 2. Estimate GHG Emission Reductions Using the ARB GHG Calculator Tool

The applicant enters the project identifier information on the "Read Me" tab of the calculator:

Project Name:	California Water Agency
Project ID:	*To be completed by DWR*
Contact Name:	John Smith
Contact Phone Number:	916-555-1234
Contact Email:	John.Smith@CAwateragency.org
Date Completed:	12/1/2016
Total Water-Energy Grant Funds Requested ($):	$500,000
Total GGRF Funds Requested, including DWR Water-Energy Grant Funds ($):	$500,000
Total Cost Share Funds ($):	$100,000
Total Project Cost ($):	$600,000

Inputs Tabs

The Inputs Tabs are designed to allow the user to enter the quantity of new measures proposed for installation. The yellow cells in the ARB GHG Calculator tool can be modified to reflect project-specific information (i.e., default assumptions). Each yellow cell is pre-populated with default assumption values. As noted above, the measures included in the project are dishwashers, clothes washers, combination ovens and pre-rinse spray valves. For this example, the input data for each measure is the same.

Commercial/Institutional Inputs (1)

Please enter the quantities of the new measure(s) proposed for replacement. Enter the project data for the new measure if known or use the defaults provided.

To see more detail on the formulas and values used in this ARB GHG calculator or to modify additional default assumptions, click on the blue tabs for the applicable project measures at the bottom of the page.

Dishwasher							
Input Data		Project Data					
Dishwasher Temp	Dishwasher Type	Quantity	Racks washed per day	Building water heater fuel type	Booster water heater fuel type	Operating days per year
Low Temperature	Under Counter	0	75	Natural Gas	N/A	365
	Stationary Single Tank Door	0	280	Natural Gas	N/A	365
	Single Tank Conveyor	0	400	Natural Gas	N/A	365
	Multi Tank Conveyor	0	600	Natural Gas	N/A	365
High Temperature	Under Counter	0	75	Natural Gas	Natural Gas	365
	Stationary Single Tank Door	0	280	Natural Gas	Natural Gas	365
	Single Tank Conveyor	0	400	Natural Gas	Natural Gas	365
	Multi Tank Conveyor	8	600	Natural Gas	Natural Gas	365
	Pot, Pan, and Utensil	0	280	Natural Gas	Natural Gas	365

Read Me | **Commercial Inputs (1)** | Commercial Inputs (2) | Commercial Inputs (3) | Residential Inputs (1) | Residential

Calcs Tab

For this example, the Commercial Dishwasher calculations tab is displayed to demonstrate the modifiable yellow cells and the energy consumption, water consumption, and reductions calculation portion of the tab—as shown below and on the following pages. For this example, the default values are used.

Commercial Dishwasher Calculations and Modifications

Inputs - *to edit these values go to the respective Inputs tab*

	DEFAULT		USER ENTRY			
	Annual days of operation	Racks washed per day	Annual days of operation	Racks washed per day	Building hot water fuel type	Booster water heater fuel type
Low Temperature						
Under Counter (1)	365	75	365	75	Natural Gas	N/A
Under Counter (2)	365	75	365	75	Natural Gas	
Under Counter (3)	365	75	365	75	Natural Gas	
Stationary Single Tank Door (1)	365	280	365	280	Natural Gas	
Stationary Single Tank Door (2)	365	280	365	280	Natural Gas	
Stationary Single Tank Door (3)	365	280	365	280	Natural Gas	
Single Tank Conveyor (1)	365	400	365	400	Natural Gas	
Single Tank Conveyor (2)	365	400	365	400	Natural Gas	
Single Tank Conveyor (3)	365	400	365	400	Natural Gas	
Multi Tank Conveyor (1)	365	600	365	600	Natural Gas	
Multi Tank Conveyor (2)	365	600	365	600	Natural Gas	
Multi Tank Conveyor (3)	365	600	365	600	Natural Gas	
High Temperature						
Under Counter (1)	365	75	365	75	Natural Gas	Natural Gas
Under Counter (2)	365	75	365	75	Natural Gas	Natural Gas
Under Counter (3)	365	75	365	75	Natural Gas	Natural Gas
Stationary Single Tank Door (1)	365	280	365	280	Natural Gas	Natural Gas
Stationary Single Tank Door (2)	365	280	365	280	Natural Gas	Natural Gas
Stationary Single Tank Door (3)	365	280	365	280	Natural Gas	Natural Gas
Single Tank Conveyor (1)	365	400	365	400	Natural Gas	Natural Gas
Single Tank Conveyor (2)	365	400	365	400	Natural Gas	Natural Gas
Single Tank Conveyor (3)	365	400	365	400	Natural Gas	Natural Gas
Multi Tank Conveyor (1)	365	600	365	600	Natural Gas	Natural Gas
Multi Tank Conveyor (2)	365	600	365	600	Natural Gas	Natural Gas
Multi Tank Conveyor (3)	365	600	365	600	Natural Gas	Natural Gas
Pot, Pan, and Utensil (1)	365	280	365	280	Natural Gas	Natural Gas
Pot, Pan, and Utensil (2)	365	280	365	280	Natural Gas	Natural Gas
Pot, Pan, and Utensil (3)	365	280	365	280	Natural Gas	Natural Gas

Calcs Tab (continued, 2 of 4)

Assumptions - *users can edit the YELLOW highlighted values to modify the assumptions*

	Average daily operation (hours)	Typical Wash Time (minutes)		Water Use per Rack (gallons)		Idle Power Draw (kW)		Equipment lifetime (years)
		Conventional	ENERGY STAR	Conventional	ENERGY STAR	Conventional	ENERGY STAR	
Low Temperature								
Under Counter (1)	18	2.0	2.0	1.73	1.19	0.50	0.50	10
Under Counter (2)	18	2.0	2.0	1.73	1.19	0.50	0.50	10
Under Counter (3)	18	2.0	2.0	1.73	1.19	0.50	0.50	10
Stationary Single Tank Door (1)	18	1.5	1.5	2.10	1.18	0.60	0.60	15
Stationary Single Tank Door (2)	18	1.5	1.5	2.10	1.18	0.60	0.60	15
Stationary Single Tank Door (3)	18	1.5	1.5	2.10	1.18	0.60	0.60	15
Single Tank Conveyor (1)	18	0.3	0.3	1.31	0.79	1.60	1.50	20
Single Tank Conveyor (2)	18	0.3	0.3	1.31	0.79	1.60	1.50	20
Single Tank Conveyor (3)	18	0.3	0.3	1.31	0.79	1.60	1.50	20
Multi Tank Conveyor (1)	18	0.3	0.3	1.04	0.54	2.00	2.00	20
Multi Tank Conveyor (2)	18	0.3	0.3	1.04	0.54	2.00	2.00	20
Multi Tank Conveyor (3)	18	0.3	0.3	1.04	0.54	2.00	2.00	20
High Temperature								
Under Counter (1)	18	2.0	2.0	1.09	0.86	0.76	0.50	10
Under Counter (2)	18	2.0	2.0	1.09	0.86	0.76	0.50	10
Under Counter (3)	18	2.0	2.0	1.09	0.86	0.76	0.50	10
Stationary Single Tank Door (1)	18	1.0	1.0	1.29	0.89	0.87	0.70	15
Stationary Single Tank Door (2)	18	1.0	1.0	1.29	0.89	0.87	0.70	15
Stationary Single Tank Door (3)	18	1.0	1.0	1.29	0.89	0.87	0.70	15
Single Tank Conveyor (1)	18	0.3	0.3	0.87	0.70	1.93	1.50	20
Single Tank Conveyor (2)	18	0.3	0.3	0.87	0.70	1.93	1.50	20
Single Tank Conveyor (3)	18	0.3	0.3	0.87	0.70	1.93	1.50	20
Multi Tank Conveyor (1)	18	0.2	0.2	0.97	0.54	2.59	2.25	20
Multi Tank Conveyor (2)	18	0.2	0.2	0.97	0.54	2.59	2.25	20
Multi Tank Conveyor (3)	18	0.2	0.2	0.97	0.54	2.59	2.25	20
Pot, Pan, and Utensil (1)	18	3.0	3.0	0.70	0.58	1.20	1.20	10
Pot, Pan, and Utensil (2)	18	3.0	3.0	0.70	0.58	1.20	1.20	10
Pot, Pan, and Utensil (3)	18	3.0	3.0	0.70	0.58	1.20	1.20	10

	Water Heater Efficiency		Water Temperature Increase (°F)
	Electric	Natural Gas	
Building Water Heater (1)	98%	80%	75
Building Water Heater (2)	98%	80%	75
Building Water Heater (3)	98%	80%	75
Booster Water Heater (1)	98%	80%	40
Booster Water Heater (2)	98%	80%	40
Booster Water Heater (3)	98%	80%	40

Specific Heat of Water	1.0	Btu/pound/°F
Density of Water	8.33	pounds/gallon

Calculations

Water Heating Energy	Electric	Natural Gas
	kWh/gallon	therm/gallon
Building Water Heater (1)	0.19	0.008
Building Water Heater (2)	0.19	0.008
Building Water Heater (3)	0.19	0.008
Booster Water Heater (1)	0.10	0.0042
Booster Water Heater (2)	0.10	0.0042
Booster Water Heater (3)	0.10	0.0042

Energy Unit Conversion	
1 therm =	100,000 Btu
1 kWh =	3,412 Btu

Calcs Tab (continued, 3 of 4)

	Annual Water Consumption (gallons)		
	Conventional	ENERGY STAR	Savings
Low Temperature			
Under Counter (1)	47,359	32,576	14,783
Under Counter (2)	47,359	32,576	14,783
Under Counter (3)	47,359	32,576	14,783
Stationary Single Tank Door (1)	214,620	120,596	94,024
Stationary Single Tank Door (2)	214,620	120,596	94,024
Stationary Single Tank Door (3)	214,620	120,596	94,024
Single Tank Conveyor (1)	191,260	115,340	75,920
Single Tank Conveyor (2)	191,260	115,340	75,920
Single Tank Conveyor (3)	191,260	115,340	75,920
Multi Tank Conveyor (1)	227,760	118,260	109,500
Multi Tank Conveyor (2)	227,760	118,260	109,500
Multi Tank Conveyor (3)	227,760	118,260	109,500
High Temperature			
Under Counter (1)	29,839	23,543	6,296
Under Counter (2)	29,839	23,543	6,296
Under Counter (3)	29,839	23,543	6,296
Stationary Single Tank Door (1)	131,838	90,958	40,880
Stationary Single Tank Door (2)	131,838	90,958	40,880
Stationary Single Tank Door (3)	131,838	90,958	40,880
Single Tank Conveyor (1)	127,020	102,200	24,820
Single Tank Conveyor (2)	127,020	102,200	24,820
Single Tank Conveyor (3)	127,020	102,200	24,820
Multi Tank Conveyor (1)	212,430	118,260	94,170
Multi Tank Conveyor (2)	212,430	118,260	94,170
Multi Tank Conveyor (3)	212,430	118,260	94,170
Pot, Pan, and Utensil (1)	71,540	59,276	12,264
Pot, Pan, and Utensil (2)	71,540	59,276	12,264
Pot, Pan, and Utensil (3)	71,540	59,276	12,264

	Annual Water Heater Energy Consumption				Annual Booster Heater Energy Consumption				Annual Idle Electricity Consumption (kWh)	
	Conventional		ENERGY STAR		Conventional		ENERGY STAR			
	Electric (kWh)	Natural Gas (therm)	Electric (kWh)	Natural Gas (therm)	Electric (kWh)	Natural Gas (therm)	Electric (kWh)	Natural Gas (therm)	Conventional	ENERGY STAR
Low Temperature										
Under Counter (1)	0	370	0	254	N/A				2,829	2,829
Under Counter (2)	0	370	0	254					2,829	2,829
Under Counter (3)	0	370	0	254					2,829	2,829
Stationary Single Tank Door (1)	0	1,676	0	942					2,409	2,409
Stationary Single Tank Door (2)	0	1,676	0	942					2,409	2,409
Stationary Single Tank Door (3)	0	1,676	0	942					2,409	2,409
Single Tank Conveyor (1)	0	1,494	0	901					9,344	8,760
Single Tank Conveyor (2)	0	1,494	0	901					9,344	8,760
Single Tank Conveyor (3)	0	1,494	0	901					9,344	8,760
Multi Tank Conveyor (1)	0	1,779	0	924					10,950	10,950
Multi Tank Conveyor (2)	0	1,779	0	924					10,950	10,950
Multi Tank Conveyor (3)	0	1,779	0	924					10,950	10,950
High Temperature										
Under Counter (1)	0	233	0	184	0	124	0	98	4,300	2,829
Under Counter (2)	0	233	0	184	0	124	0	98	4,300	2,829
Under Counter (3)	0	233	0	184	0	124	0	98	4,300	2,829
Stationary Single Tank Door (1)	0	1,030	0	710	0	549	0	379	4,234	3,407
Stationary Single Tank Door (2)	0	1,030	0	710	0	549	0	379	4,234	3,407
Stationary Single Tank Door (3)	0	1,030	0	710	0	549	0	379	4,234	3,407
Single Tank Conveyor (1)	0	992	0	798	0	529	0	426	11,271	8,760
Single Tank Conveyor (2)	0	992	0	798	0	529	0	426	11,271	8,760
Single Tank Conveyor (3)	0	992	0	798	0	529	0	426	11,271	8,760
Multi Tank Conveyor (1)	0	1,659	0	924	0	885	0	493	15,126	13,140
Multi Tank Conveyor (2)	0	1,659	0	924	0	885	0	493	15,126	13,140
Multi Tank Conveyor (3)	0	1,659	0	924	0	885	0	493	15,126	13,140
Pot, Pan, and Utensil (1)	0	559	0	463	0	298	0	247	1,752	1,752
Pot, Pan, and Utensil (2)	0	559	0	463	0	298	0	247	1,752	1,752
Pot, Pan, and Utensil (3)	0	559	0	463	0	298	0	247	1,752	1,752

Calcs Tab (continued, 4 of 4)

Annual energy consumption per dishwasher

	Conventional		ENERGY STAR		Savings	
	Electric (kWh)	Natural Gas (therm)	Electric (kWh)	Natural Gas (therm)	Electric (kWh)	Natural Gas (therm)
Low Temperature						
Under Counter (1)	2,829	370	2,829	254	0	115
Under Counter (2)	2,829	370	2,829	254	0	115
Under Counter (3)	2,829	370	2,829	254	0	115
Stationary Single Tank Door (1)	2,409	1,676	2,409	942	0	734
Stationary Single Tank Door (2)	2,409	1,676	2,409	942	0	734
Stationary Single Tank Door (3)	2,409	1,676	2,409	942	0	734
Single Tank Conveyor (1)	9,344	1,494	8,760	901	584	593
Single Tank Conveyor (2)	9,344	1,494	8,760	901	584	593
Single Tank Conveyor (3)	9,344	1,494	8,760	901	584	593
Multi Tank Conveyor (1)	10,950	1,779	10,950	924	0	855
Multi Tank Conveyor (2)	10,950	1,779	10,950	924	0	855
Multi Tank Conveyor (3)	10,950	1,779	10,950	924	0	855
High Temperature						
Under Counter (1)	4,300	357	2,829	282	1,471	75
Under Counter (2)	4,300	357	2,829	282	1,471	75
Under Counter (3)	4,300	357	2,829	282	1,471	75
Stationary Single Tank Door (1)	4,234	1,579	3,407	1,089	827	490
Stationary Single Tank Door (2)	4,234	1,579	3,407	1,089	827	490
Stationary Single Tank Door (3)	4,234	1,579	3,407	1,089	827	490
Single Tank Conveyor (1)	11,271	1,521	8,760	1,224	2,511	297
Single Tank Conveyor (2)	11,271	1,521	8,760	1,224	2,511	297
Single Tank Conveyor (3)	11,271	1,521	8,760	1,224	2,511	297
Multi Tank Conveyor (1)	15,126	2,544	13,140	1,416	1,986	1,128
Multi Tank Conveyor (2)	15,126	2,544	13,140	1,416	1,986	1,128
Multi Tank Conveyor (3)	15,126	2,544	13,140	1,416	1,986	1,128
Pot, Pan, and Utensil (1)	1,752	857	1,752	710	0	147
Pot, Pan, and Utensil (2)	1,752	857	1,752	710	0	147
Pot, Pan, and Utensil (3)	1,752	857	1,752	710	0	147

References - Commercial

Equipment specifications:	- ENERGY STAR specification
	- EPA/Food Service Technology Center (FSTC) research on available models, 2013
Operating hours:	- EPA/FSTC research on average use, 2009
Equipment lifetime:	- EPA/FSTC research on available models, 2013
Water heater specifications:	-Federal standard: Title 10 Part 431 - Energy Efficiency Program for Certain Commercial and Industrial Equipment; subpart G
Water properties:	- USGS water science school - water properties
Water temperature increase	-Assumes an outlet temperature of 135° F and an inlet temperature of 60° F

Inlet water temperature by climate zone

Climate Zone	Inlet Water Temperature
1	53.90
2	57.52
3	57.69
4	59.12
5	57.93
6	61.55
7	62.63
8	62.97
9	63.76
10	63.76
11	61.00
12	59.65
13	63.99
14	61.48
15	73.55
16	50.54

Enter site-specific water heater temperatures

Tab	Outlet Temp	Inlet Temp	Temp increase
Commerical Inputs (1) Tab	135	60	75
Commerical Inputs (2) Tab	135	60	75
Commerical Inputs (3) Tab	135	60	75

Residential Inputs (3) | Results Summary | Program Summary | Com. Dishwasher Calcs | Com. Clothes Washer Calcs | Com. Ice Machine

Results Summary Tab

Project data results for Commercial/Institutional and Residential measures are accessed through the “Results Summary” tab. The “Results Summary” tab displays the annual and project GHG emission reductions, energy savings and water savings per measure.

Program Summary Tab

The “Program Summary” tab provides the project reporting metrics and a summary of the overall project reductions. Note that the displayed results in this example represent the summation of multiple measures and not just dishwashers, as illustrated.

Project Name:	**California Water Agency**
Project ID:	***To be completed by DWR***

Results	GHG Emissions (MTCO2e)	Description
Total Project GHG Emission Reductions	1,233	Total GHG Emission Reductions (MTCO2e).
Water-Energy Grant Funds Requested ($)	$ 500,000	Total DWR Water-Energy Grant fund requested.
Total GGRF Funds Requested, including DWR Water-Energy Grant Funds ($)	$ 500,000	Total GGRF Funds Requested for the proposed project, including DWR Water-Energy Grant funds. If you are applying, have applied, or are planning to apply for additional GGRF funds for the proposed project, enter the combined funding request for all GGRF programs. If you are applying only to DWR for GGRF funding, re-enter the Water-Energy Grant funds requested.
Total Cost Share Funds ($)	$ 100,000	Total non-GGRF cost share funds
Total Project Cost ($)	$ 600,000	Total project cost includes DWR Water-Energy Grant requested, any additional GGRF funds requested, and any cost share funds.
Total GHG Emission Reductions (MTCO2e) per Water-Energy Funds Requested ($)	0.0025	Total Reductions per DWR Water-Energy Grant funds requested.
Total GHG Emission Reductions (MTCO2e) per Total GGRF Funds Requested ($)	0.0025	Total Reductions per Total GGRF funds requested.

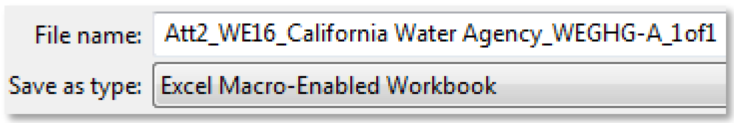
Due to DWR Program requirements, additional results are estimated using the ARB GHG Calculator tool and are reported below.

Results	Annual Savings	Project Savings
Energy Savings in Electricity (kWh)	43,222	539,767
Energy Savings of Natural Gas (therms)	11,201	201,179
Total Energy Savings (kWh)	371,517	6,435,983
Total Energy Savings (kWh) over Total Cost ($)	0.74	12.87
Total GHG Emission Reductions (MTCO2e) over Total Cost	0.00015	0.00247
Water Savings (gallons)	1,152,232	18,958,100
Water Savings (gallons) over Total Cost ($)	2.30	37.92

Information for Documentation

Total Project GHG Emission Reductions are automatically calculated from the ARB GHG Calculator tool. The summary documentation that provides the GHG emission reductions from the project can be found in the "Program Summary" tab of the calculator.

Save the file as instructed on the "Read Me" tab:



Applicants must submit the completed calculator along with any other required documentation to DWR. To complete the quantification process, the applicant must submit an electronic copy of the calculator (saved as a ".xlsm" or "Excel Macro-Enabled Workbook" file type) and all of the required documentation, as noted in Section C of the quantification methodology.

Appendix B. GHG Emission Reductions, Energy Savings, and Water Savings Calculations

Commercial Dishwashers

$$E_{water\ heating} = \frac{T_{increase}\ x\ c_{water}\ x\ \rho_{water}}{\eta_{water\ heater}}\ x\ conversion \quad \textbf{(Eq. 1)}$$

$$H2O_{\ dishwasher} = H2O_{per\ rack}\ x\ racks_{\ per\ day}\ x\ days_{operation} \quad \textbf{(Eq. 2)}$$

$$H2O_{savings} = H2O_{conventional} - H2O_{Energy\ Star} \quad \textbf{(Eq. 3)}$$

$$WH_{dishwasher} = H2O_{consumption}\ x\ E_{water\ heating} \quad \textbf{(Eq. 4)}$$

$$Electricity_{idle} = P_{idle}\ ((Hours_{daily}\ x\ Days_{operation}) - (\frac{Days_{operation}\ x\ racks_{per\ day}\ x\ Time_{wash}}{60})) \quad \textbf{(Eq. 5)}$$

$$E_{low\ temp} = WH_{dishwasher} + Electricity_{idle} \quad \textbf{(Eq. 6)}$$

$$E_{high\ temp} = WH_{dishwasher} + BH_{dishwasher} + Electricity_{idle} \quad \textbf{(Eq. 7)}$$

$$E_{savings} = E_{conventional} - E_{Energy\ Star} \quad \textbf{(Eq. 8)}$$

$$GHG_{electricty} = E_{electricity\ savings}\ x\ EF_{electricity} \quad \textbf{(Eq. 9)}$$

$$GHG_{natural\ gas} = E_{natural\ gas\ savings}\ x\ EF_{natural\ gas} \quad \textbf{(Eq. 10)}$$

Where:

- $E_{water\ heating}$ = water heating energy. The amount of energy required to heat water above the initial inlet temperature to the final outlet temperature (kWh/gallon or therm/gallon)
- $T_{increase}$ = the increase in water temperature. The average water temperature increase is 75º assuming an average inlet temperature of 60º and an outlet water temperature of 135º (ºF)
- C_{water} = specific heat of water, 1.0 Btu/pound/ºF
- ρ_{water} = density of water, 8.33 pounds/gallon
- $\eta_{water\ heater}$ = efficiency of the water heater (%)
- conversion = energy conversion
    - 1 KWh = 3,412 Btu
    - 1 therm = 100,000 Btu
- $H2O_{dishwasher}$ = annual quantity of water consumed by the dishwasher (conventional or Energy Star model) (gallons)

- $\underline{H2O_{per\ rack}}$ = quantity of water consumed per rack or "load" of dishes, consisting of rinsing and sanitizing, in the dishwasher for one cycle (gallons)
- $\underline{racks_{per\ day}}$ = quantity of racks or "loads" washed per day per dishwasher
- $\underline{days_{operation}}$ = annual days of dishwasher operation. Default value of 365 (days)
- $\underline{H2O_{savings}}$ = quantity of water saved by replacing conventional model with Energy Star model (gallons)
- $\underline{H2O_{conventional}}$ = quantity of water consumed by the conventional or "pre-existing" model (gallons)
- $\underline{H2O_{Energy\ Star}}$ = quantity of water consumed by the Energy Star model (gallons)
- $\underline{WH_{dishwasher}}$ = annual water heater hot water energy consumed by the dishwasher (kWh or therm)
- $\underline{Electricity_{idle}}$ = idle electricity consumption. Annual electricity consumed by the dishwasher while maintaining wash tank water at the thermostat set point during operation (kWh)
- $\underline{P_{idle}}$ = idle power draw. Electricity load consumed by dishwasher during "stand-by" mode (kW)
- $\underline{Hours_{daily}}$ = average daily use of dishwasher specific to facility type (hours)
- $\underline{Time_{wash}}$ = amount of time spent in wash mode based on the dishwasher type (min)
- $\underline{60}$ = conversion from minutes to hours
- $\underline{E_{low\ temp}}$ = annual hot water and electricity energy consumption per low temperature dishwasher (kWh + therm or kWh)
- $\underline{E_{high\ temp}}$ = annual hot water and electricity energy consumption per high temperature dishwasher (kWh + therm or kWh)
- $\underline{BH_{dishwasher}}$ = annual booster heater hot water energy consumed by a high temperature dishwasher (kWh or therm)
- $\underline{E_{savings}}$ = quantity of energy saved by replacing conventional model with Energy Star model (kWh + therm or kWh)
- $\underline{E_{conventional}}$ = quantity of energy consumed by the conventional or "pre-existing" model (kWh + therm or kWh)
- $\underline{E_{Energy\ Star}}$ = quantity of energy consumed by the Energy Star model (kWh + therm or kWh)
- $\underline{GHG_{electricity}}$ = annual GHG emission reductions as a result of electricity savings ($MTCO_2e$)
- $\underline{E_{electricity\ savings}}$ = quantity of electricity saved by replacing conventional model with Energy Star model (kWh)

- EF electricity = emission factor for electricity (0.000303 $MTCO_2e$/kWh)[12]
- GHG natural gas = annual GHG emission reductions as a result of natural gas savings ($MTCO_2e$)
- E natural gas savings = quantity of natural gas saved by replacing conventional model with Energy Star model (therms)
- EF natural gas = emission factor for natural gas (0.00531 $MTCO_2e$/therm)[13]

Commercial Clothes Washers

$$Electricity_{rated\ consumption} = Electricity_{rated-DOE}\ x\ \frac{Loads_{per\ year}}{Loads_{reference}} \quad \textbf{(Eq. 11)}$$

$$Electricity_{washer\ total} = \frac{capacity}{MEF}\ x\ Loads_{per\ year} \quad \textbf{(Eq. 12)}$$

$$Electricity_{machine} = Electricity_{machine\ portion}\ x\ Electricity_{rated\ consumption} \quad \textbf{(Eq. 13)}$$

$$WH_{electricity} = Electricity_{water\ heating\ portion}\ x\ Electrcity_{rated\ consumption} \quad \textbf{(Eq. 14)}$$

$$WH_{natural\ gas} = \frac{Electricity_{water\ heating\ portion}\ x\ Electricity_{rated\ consumption}}{\eta_{gas\ water\ heater}}\ x\ conversion \quad \textbf{(Eq. 15)}$$

$$Dryer_{electricity} = (Electricity_{washer\ total} - Electricity_{rated\ consumption})\ x\ \frac{\%_{loads\ dried}}{DUF}\ x\ DU \quad \textbf{(Eq. 16)}$$

$$Dryer_{natural\ gas} = (Electricity_{washer\ total} - Electricity_{rated\ consumption})\ x\ \frac{\%_{loads\ dried}}{DUF}\ x\ DU\ x\ GCF \quad \textbf{(Eq. 17)}$$

$$E_{electricity} = E_{machine\ electrical} + WH_{electricity} + Dryer_{electricity} \quad \textbf{(Eq. 18)}$$

$$E_{natural\ gas} = WH_{natural\ gas} + Dryer_{natural\ gas} \quad \textbf{(Eq. 19)}$$

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[12] For the purposes of GGRF quantification methodologies, ARB developed a California grid electricity emission factor based on 2013 data for total in-state and imported electricity emissions (89,840,000 MTCO2e) divided by total consumption (296,203,000 MWh). Emissions data for 2013 were obtained from the ARB GHG inventory, dated March 30, 2016, available online at: http://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_sector_sum_2000-14.pdf.
Consumption data for 2013 were obtained from the CEC Energy Almanac, as of September 10, 2015, available online at: http://energyalmanac.ca.gov/electricity/electricity_generation.html.

[13] EPA Emission Factors for Greenhouse Gas Inventories, as of November 19, 2016, available online at: http://www.epa.gov/sites/production/files/2015-12/documents/emission-factors_nov_2015.pdf
The EPA emission factor GHG inventory units provided for carbon dioxide (CO_2) are kg/mmBtu; for methane (CH_4) and nitrous oxide (N_2O) the units are g/mmBtu. CH_4 and N_2O are converted to carbon dioxide equivalents (CO_2e) by multiplying by their global warming potential (GWP), 25 and 298, respectively.

$$H2O_{annual} = WF\ x\ capacity\ x\ Loads_{per\ week}\ x\ weeks_{annual} \quad \textbf{(Eq. 20)}$$

$$H2O_{savings} = H2O_{conventional} - H2O_{Energy\ Star} \quad \textbf{(Eq. 21)}$$

$$E_{savings} = E_{conventional} - E_{Energy\ Star} \quad \textbf{(Eq. 22)}$$

$$GHG_{electricty} = E_{electricity\ savings}\ x\ EF_{electricity} \quad \textbf{(Eq. 23)}$$

$$GHG_{natural\ gas} = E_{natural\ gas\ savings}\ x\ EF_{natural\ gas} \quad \textbf{(Eq. 24)}$$

Where:

- Electricity $_{rated\ consumption}$ = estimated annual rated electricity consumption of the clothes washer based on the DOE rated electricity consumption undergoing the DOE test procedure and the ratio of loads washed per year in a commercial facility type against a reference load of 392 loads per year as determined by DOE (kWh/year)
- Electricity $_{rated\text{-}DOE}$ = estimated annual electricity consumption of the clothes washer under typical conditions consisting of the electricity consumed by the washer machine and the energy needed to heat the water used by the washer machine with an electric water heater. The electricity rated consumption is based on 392 loads per year as referenced by the DOE test procedure (kWh/year)
- Loads $_{per\ year}$ = number of loads per year per clothes washer used in commercial applications
- Loads $_{reference}$ = number (392) of loads used in the DOE test procedure as part of the uniform test method for measuring the energy consumption of clothes washers
- Electricity $_{washer\ total}$ = annual electricity consumption of the clothes washer, based on an electric water heater, consisting of the electricity consumed by the washer machine, hot water energy consumption, and the dryer energy required for the removal of the remaining moisture in the wash load with an electric dryer (kWh/year)
- capacity = tub capacity of clothes washer as measured by the DOE test procedure (cubic feet, ft^3)
- MEF = modified energy factor. The energy metric for commercial clothes washers, where, the higher the metric, the more efficient the clothes washer (ft^3/kWh)

  $MEF = \frac{capacity}{M+E+D}$

  Where:
  - M = Electricity $_{machine}$
  - E = WH $_{electricity}$
  - D = Dryer $_{electricity}$
- Electricity $_{machine}$ = electrical energy consumed by the washer machine during wash mode (kWh)

- Electricity $_{machine\ portion}$ = portion of electricity consumed by the washer machine during wash mode as compared to the electricity (hot water energy) consumed by the washer machine with an electric water heater (%)
- WH $_{electricity}$ = electrical hot water energy consumed by the clothes washer with an electric water heater (kWh)
- Electricity $_{water\ heating\ portion}$ = portion of electrical hot water energy consumed by the clothes washer with an electric water heater as compared to the electricity consumed by the clothes washer during wash mode (%)
- $\eta_{gas\ water\ heater}$ = natural gas water heater efficiency (%)
- conversion = energy conversion
  - 1 KWh = 3,412 Btu
  - 1 therm = 100,000 Btu
- Dryer $_{electricity}$ = electricity consumed by an electric dryer for the removal of the remaining moisture from the wash load (kWh)
- % $_{loads\ dried}$ = percentage of wash loads dried in a clothes dryer as determined by the calculator user. Default is 100%.
- DUF = dryer usage factor, percentage of wash loads dried in a clothes dryer (0.84) as determined by the DOE test procedure
- DU = dryer usage in buildings or households with both a clothes washer and clothes dryer (0.95)
- Dryer $_{natural\ gas}$ = energy consumed by the natural gas dryer for the removal of the remaining moisture from the wash load (therms)
- GCF = natural gas correction factor to account for the additional energy required by a gas dryer to dry clothes relative to an electric dryer (1.12)
- E $_{electricity}$ = annual quantity of electricity consumed by either the conventional or Energy Star clothes washer (kWh)
- E $_{natural\ gas}$ = annual quantity of natural gas consumed by either the conventional or Energy Star clothes washer (therms)
- H2O $_{annual}$ = annual quantity of water consumed by either the conventional or Energy Star clothes washer (gallons)
- WF = water factor, the metric for the water performance of the commercial clothes washer. The lower the WF, the more efficient the clothes washer (gallons/ft^3)

  $$WF = \frac{Q}{capacity}$$

  Where:
  - Q = total weighted per-cycle water consumption (gallons)
- Loads $_{per\ week}$ = number of loads per week per clothes washer used in commercial applications
- weeks $_{per\ year}$ = number of weeks throughout the year the clothes washer is used. Default value of 52 (weeks)
- H2O $_{savings}$ = quantity of water saved by replacing conventional model with Energy Star model (gallons)

- H2O $_{conventional}$ = quantity of water consumed by the conventional or "pre-existing" model (gallons)
- H2O $_{Energy\ Star}$ = quantity of water consumed by the Energy Star model (gallons)
- E $_{savings}$ = quantity of energy saved by replacing conventional model with Energy Star model (kWh + therm or kWh)
- E $_{conventional}$ = quantity of energy consumed by the conventional or "pre-existing" model (kWh + therm or kWh)
- E $_{Energy\ Star}$ = quantity of energy consumed by the Energy Star model (kWh + therm or kWh)
- GHG $_{electricity}$ = annual GHG emission reductions as a result of electricity savings ($MTCO_2e$)
- E $_{electricity\ savings}$ = quantity of electricity saved by replacing conventional model with Energy Star model (kWh)
- EF $_{electricity}$ = emission factor for electricity (0.000303 $MTCO_2e$/kWh)
- GHG $_{natural\ gas}$ = annual GHG emission reductions as a result of natural gas savings ($MTCO_2e$)
- E $_{natural\ gas\ savings}$ = quantity of natural gas saved by replacing conventional model with Energy Star model (therms)
- EF $_{natural\ gas}$ = emission factor for natural gas (0.00531 $MTCO_2e$/therm)

Commercial Ice Machines

$$Ice_{production} = H\ x\ Days_{operation}\ x\ Duty\ Cycle \qquad \textbf{(Eq. 25)}$$

$$Rate_{energy\ consumption} = A\ x\ H^{a} - b \qquad \textbf{(Eq. 26)}$$

Where:

- Rate $_{energy\ consumption}$ = the energy consumption rate requirement level. "H" is the ice harvest rate for the system, "A" is a coefficient, "a" is an exponent, and "b" is a constant. Depending on ice machine equipment type, the following equations are the energy consumption rate equations for both conventional and Energy Star models.
- **Conventional**
  - Batch Ice Making Head with Ice Harvest Rate (H) $< 450 = 10.26 - 0.0086\ x\ H$
  - Batch Ice Making Head with Ice Harvest Rate (H) $> 450 = 6.89 - 0.0011\ x\ H$
  - Batch Remote Condensing Unit / Split System with Ice Harvest Rate (H) $< 1{,}000 = 8.85 - 0.003\ x\ H$
  - Batch Remote Condensing Unit / Split System with Ice Harvest Rate (H) $> 1{,}000 = 5.1$
  - Batch Self Contained Unit with Ice Harvest Rate (H) $< 175 = 18 - 0.0469\ x\ H$
  - Batch Self Contained Unit with Ice Harvest Rate (H)

$> 175 = 9.8$
- o Continuous Ice Making Head
  $9.18\ x\ (H^{-0.057}) + 1$
- o Continuous Remote Condensing Unit / Split system
  $6\ x\ (H^{-0.162}) + 4.2$
- o Continuous Self Contained Unit
  $59.45\ x\ (H^{-0.349}) + 0.68$

- **Energy Star**
  - o Batch Ice Making Head
    $37.72\ x\ H^{-0.298}$
  - o Batch Remote Condensing Unit / Split System with Ice Harvest Rate (H) $< 1{,}600 = 22.95\ x\ H^{-0.258}$
  - o Batch Remote Condensing Unit / Split System with Ice Harvest Rate (H) $> 1{,}600 = -0.00011\ x\ H + 4.6$
  - o Batch Self Contained Unit
    $48.66\ x\ (H^{-0.326}) + 0.08$
  - o Continuous Ice Making Head
    $9.18\ x\ (H^{-0.057})$
  - o Continuous Remote Condensing Unit / Split system
    $6\ x\ (H^{-0.162}) + 3.5$
  - o Continuous Self Contained Unit
    $59.45\ x\ (H^{-0.349}) + 0.08$

$$E_{ice\ machine} = \frac{Rate_{energy\ consumption}\ x\ Ice_{production}}{100}$$ **(Eq. 27)**

$$H2O_{ice\ machine} = \frac{H2O_{ice\ making}\ x\ Ice_{production}}{100}$$ **(Eq. 28)**

$$H2O_{savings} = H2O_{conventional} - H2O_{Energy\ Star}$$ **(Eq. 29)**

$$E_{savings} = E_{conventional} - E_{Energy\ Star}$$ **(Eq. 30)**

$$GHG_{electricty} = E_{electricity\ savings}\ x\ EF_{electricity}$$ **(Eq. 31)**

$$GHG_{natural\ gas} = E_{natural\ gas\ savings}\ x\ EF_{natural\ gas}$$ **(Eq. 32)**

Where:
- $Ice_{production}$ = annual quantity of ice produced from the ice machine (pounds)
- H = ice harvest rate, the gross weight of ice harvested (pounds/day)
- $Days_{operation}$ = annual days of dishwasher operation. Default value of 365 (days)
- Duty cycle = proportion of time throughout the day that the ice machine is operated (%)

- Rate $_{\text{energy consumption}}$ = energy consumption rate or total energy input rate. Rate of electricity consumed per production of 100 pounds of ice. Each ice machine type will have a different energy consumption rate (kWh/100 pounds of ice)
- Batch-type ice maker = an ice maker having alternate freezing and harvesting periods.
- Continuous-type ice maker = an ice maker that continually freezes and harvests ice at the same time.
- Ice making head = a model with the ice-making mechanism and the condensing unit in a single package, but with a separate ice storage bin.
- Remote condensing unit or split system unit = a model in which the ice-making mechanism and condenser or condensing unit are in separate sections. This includes ice makers with and without remote compressor.
- Self-contained unit = a model in which the ice-making mechanism and storage compartment are in an integral cabinet.
- $E_{\text{ice machine}}$ = annual energy consumption based on ice machine type (kWh)
- 100 = used to convert “100 pounds of ice” to “pounds of ice”
- $H2O_{\text{ice machine}}$ = annual water consumption based on ice machine type (gallons)
- $H2O_{\text{ice making}}$ = quantity of potable water used in ice making (gallon/100 pounds of ice)
- $H2O_{\text{savings}}$ = quantity of water saved by replacing conventional model with Energy Star model (gallons)
- $H2O_{\text{conventional}}$ = quantity of water consumed by the conventional or “pre-existing” model (gallons)
- $H2O_{\text{Energy Star}}$ = quantity of water consumed by the Energy Star model (gallons)
- E_{savings} = quantity of energy saved by replacing conventional model with Energy Star model (kWh)
- $E_{\text{conventional}}$ = quantity of energy consumed by the conventional or “pre-existing” model (kWh)
- $E_{\text{Energy Star}}$ = quantity of energy consumed by the Energy Star model (kWh)
- $GHG_{\text{electricity}}$ = annual GHG emission reductions as a result of electricity savings ($MTCO_2e$)
- $E_{\text{electricity savings}}$ = quantity of electricity saved by replacing conventional model with Energy Star model (kWh)
- $EF_{\text{electricity}}$ = emission factor for electricity (0.000303 $MTCO_2e$/kWh)
- $GHG_{\text{natural gas}}$ = annual GHG emission reductions as a result of natural gas savings ($MTCO_2e$)
- $E_{\text{natural gas savings}}$ = quantity of natural gas saved by replacing conventional model with Energy Star model (therms)
- $EF_{\text{natural gas}}$ = emission factor for natural gas (0.00531 $MTCO_2e$/therm)

Commercial Steam Cookers

$$Hours_{annual} = Hours_{daily}\ x\ Days_{operation} \quad \textbf{(Eq. 33)}$$

$$E_{cooking} = \frac{Food_{per\ day}\ x\ E_{ASTM}}{\eta_{cooking\ energy}} \quad \textbf{(Eq. 34)}$$

$$t_{idle} = Hours_{daily} - \frac{Food_{per\ day}}{production_{per\ pan}\ x\ pans_{per\ unit}} \quad \textbf{(Eq. 35)}$$

$$E_{idle} = ((1 - t_{steam\ mode})\ x\ Rate_{idle} + \frac{t_{steam\ mode}\ x\ capacity_{per\ pan}\ x\ pans_{per\ unit}\ x\ E_{ASTM}}{\eta_{cooking\ energy}})\ x\ t_{idle} \quad \textbf{(Eq. 36)}$$

$$E_{daily} = E_{cooking} + E_{idle} \quad \textbf{(Eq. 37)}$$

$$E_{steam\ cooker} = \frac{E_{daily}\ x\ Days_{operation}}{conversion} \quad \textbf{(Eq. 38)}$$

$$H2O_{steam\ cooker} = H2O_{per\ hour}\ x\ Hours_{annual} \quad \textbf{(Eq. 39)}$$

$$H2O_{savings} = H2O_{conventional} - H2O_{Energy\ Star} \quad \textbf{(Eq. 40)}$$

$$E_{savings} = E_{conventional} - E_{Energy\ Star} \quad \textbf{(Eq. 41)}$$

$$GHG_{electricty} = E_{electricity\ savings}\ x\ EF_{electricity} \quad \textbf{(Eq. 42)}$$

$$GHG_{natural\ gas} = E_{natural\ gas\ savings}\ x\ EF_{natural\ gas} \quad \textbf{(Eq. 43)}$$

Where:

- $Hours_{annual}$ = annual hours of operation of the steam cooker (hours)
- $Hours_{daily}$ = daily hours of operation of the steam cooker (hours)
- $Days_{operation}$ = annual days of steam cooker operation. Default value is 365 (days)
- $E_{cooking}$ = daily cooking energy output by the steam cooker during unit operation (Wh or Btu)
- $Food_{per\ day}$ = quantity of food cooked per day in the steam cooker (pounds)
- E_{ASTM} = the heat energy input required during cooking per pound of food as measured by the American Society for testing and Materials (ASTM) (Wh/pound or Btu/pound)
- $\eta_{cooking\ energy}$ = the quantity of energy input to the food products (%)

- t_{idle} = daily amount of idle time of the steam cooker while maintaining a stabilized operating temperature (hours)
- $production_{per\ pan}$ = production capacity of food per steam cooker pan (pounds/hour)
- $pans_{per\ unit}$ = number of pans per steam cooker unit
- E_{idle} = daily idle energy consumed by the steam cooker when the unit is maintaining a stabilized operating temperature (Wh or Btu)
- $t_{steam\ mode}$ = the amount of time the steam cooker is being utilized to cook food expressed as a percentage (%)
- $Rate_{idle}$ = energy idle rate, the rate of steam cooker energy consumption while maintaining a stabilized operating temperature (W or Btu/hour)
- E_{daily} = total daily energy consumed by the steam cooker (Wh or Btu)
- $E_{steam\ cooker}$ = annual energy consumption per steam cooker (kWh or therms)
- Conversion
  - kW = 1,000 W
  - therm = 100,000 Btu
- $H2O_{steam\ cooker}$ = annual water consumption per steam cooker (gallons)
- $H2O_{per\ hour}$ = quantity of water consumed per hour per steam cooker (gallons/hour)
- $H2O_{savings}$ = quantity of water saved by replacing conventional model with Energy Star model (gallons)
- $H2O_{conventional}$ = quantity of water consumed by the conventional or "pre-existing" model (gallons)
- $H2O_{Energy\ Star}$ = quantity of water consumed by the Energy Star model (gallons)
- $E_{savings}$ = quantity of energy saved by replacing conventional model with Energy Star model (kWh or therms)
- $E_{conventional}$ = quantity of energy consumed by the conventional or "pre-existing" model (kWh or therms)
- $E_{Energy\ Star}$ = quantity of energy consumed by the Energy Star model (kWh or therms)
- $GHG_{electricity}$ = annual GHG emission reductions as a result of electricity savings ($MTCO_2e$)
- $E_{electricity\ savings}$ = quantity of electricity saved by replacing conventional model with Energy Star model (kWh)
- $EF_{electricity}$ = emission factor for electricity (0.000303 $MTCO_2e$/kWh)
- $GHG_{natural\ gas}$ = annual GHG emission reductions as a result of natural gas savings ($MTCO_2e$)
- $E_{natural\ gas\ savings}$ = quantity of natural gas saved by replacing conventional model with Energy Star model (therms)
- $EF_{natural\ gas}$ = emission factor for natural gas (0.00531 $MTCO_2e$/therm)

Commercial Combination Ovens

$$E_{cooking} = \frac{Food_{per\ day}\ x\ E_{ASTM}\ x\ Mode_{\%\ food\ cooked}}{\eta_{cooking\ energy}} \quad \textbf{(Eq. 44)}$$

$$t_{idle} = (Hours_{daily} - \frac{Food_{per\ day}}{production_{per\ mode}})\ x\ Mode_{\%\ food\ cooked} \quad \textbf{(Eq. 45)}$$

$$E_{idle} = Rate_{idle}\ x\ t_{idle} \quad \textbf{(Eq. 46)}$$

$$E_{daily} = E_{cooking} + E_{idle} \quad \textbf{(Eq. 47)}$$

$$E_{combination\ oven} = \frac{E_{daily}\ x\ Days_{operation}}{conversion} \quad \textbf{(Eq. 48)}$$

$$H2O_{combination\ oven} = H2O_{per\ hour}\ x\ Hours_{daily}\ x\ Days_{operation} \quad \textbf{(Eq. 49)}$$

$$H2O_{savings} = H2O_{conventional} - H2O_{Energy\ Star} \quad \textbf{(Eq. 50)}$$

$$E_{savings} = E_{conventional} - E_{Energy\ Star} \quad \textbf{(Eq. 51)}$$

$$GHG_{electricty} = E_{electricity\ savings}\ x\ EF_{electricity} \quad \textbf{(Eq. 52)}$$

$$GHG_{natural\ gas} = E_{natural\ gas\ savings}\ x\ EF_{natural\ gas} \quad \textbf{(Eq. 53)}$$

Where:

- $E_{cooking}$ = daily cooking energy output by the combination oven during unit operation (Wh or Btu)
- $Food_{per\ day}$ = quantity of food cooked per day in the combination oven (pounds)
- E_{ASTM} = the heat energy input required during cooking per pound of food as measured by the American Society for Testing and Materials (ASTM) (Wh/pound or Btu/pound)
- $\eta_{cooking\ energy}$ = the quantity of energy input to the food products (%)
- $Mode_{\%\ food\ cooked}$ = percentage of food cooked in either the convection mode or steam mode of the combination oven (%)
- t_{idle} = daily amount of idle time of the combination oven while maintaining a stabilized operating temperature (hours)
- $Hours_{daily}$ = daily hours of operation of the combination oven (hours)
- $production_{per\ mode}$ = production capacity of food per either convection mode or steam mode (pounds/hour)
- E_{idle} = daily idle energy consumed by the combination oven when the unit is maintaining a stabilized operating temperature (Wh or Btu)
- $Rate_{idle}$ = energy idle rate, the rate of energy consumption while maintaining a stabilized operating temperature (W or Btu/hour)
- E_{daily} = total daily energy consumed by the combination oven (Wh or Btu)

- $E_{combination\ oven}$ = annual energy consumption per combination oven (kWh or therms)
- $Days_{operation}$ = annual days of combination oven operation. Default value is 365 (days)
- Conversion
  - o kW = 1,000 W
  - o therm = 100,000 Btu
- $H2O_{combination\ oven}$ = annual water consumption per combination oven (gallons)
- $H2O_{per\ hour}$ = quantity of water consumed per hour per combination oven (gallons/hour)
- $H2O_{savings}$ = quantity of water saved by replacing conventional model with Energy Star model (gallons)
- $H2O_{conventional}$ = quantity of water consumed by the conventional or "pre-existing" model (gallons)
- $H2O_{Energy\ Star}$ = quantity of water consumed by the Energy Star model (gallons)
- $E_{savings}$ = quantity of energy saved by replacing conventional model with Energy Star model (kWh or therms)
- $E_{conventional}$ = quantity of energy consumed by the conventional or "pre-existing" model (kWh or therms)
- $E_{Energy\ Star}$ = quantity of energy consumed by the Energy Star model (kWh or therms)
- $GHG_{electricity}$ = annual GHG emission reductions as a result of electricity savings ($MTCO_2e$)
- $E_{electricity\ savings}$ = quantity of electricity saved by replacing conventional model with Energy Star model (kWh)
- $EF_{electricity}$ = emission factor for electricity (0.000303 $MTCO_2e$/kWh)
- $GHG_{natural\ gas}$ = annual GHG emission reductions as a result of natural gas savings ($MTCO_2e$)
- $E_{natural\ gas\ savings}$ = quantity of natural gas saved by replacing conventional model with Energy Star model (therms)
- $EF_{natural\ gas}$ = emission factor for natural gas (0.00531 $MTCO_2e$/therm)

Commercial Pre-Rinse Spray Valves

$$H2O_{PRSV} = Rate_{flow}\ x\ Hours_{daily}\ x\ Days_{operation} \quad \textbf{(Eq. 54)}$$

$$E_{PRSV} = \frac{H2O_{hot\ water\ \%}\ x\ T_{increase}\ x\ C_{water}\ x\ \rho_{water}}{\eta_{water\ heater}}\ x\ conversion\ x\ H2O_{PRSV} \quad \textbf{(Eq. 55)}$$

$$H2O_{savings} = H2O_{conventional} - H2O_{WaterSense} \quad \textbf{(Eq. 56)}$$

$$E_{savings} = E_{conventional} - E_{WaterSense} \quad \textbf{(Eq. 57)}$$

$$GHG_{electricty} = E_{electricity\ savings}\ x\ EF_{electricity} \quad \textbf{(Eq. 58)}$$

$$GHG_{natural\ gas} = E_{natural\ gas\ savings}\ x\ EF_{natural\ gas} \quad \textbf{(Eq. 59)}$$

Where:

- $H2O_{PRSV}$ = annual water consumption of the pre-rinse spray valve (gallons)
- $Rate_{flow}$ = flow rate of the commercial pre-rinse spray valve for both conventional or EPA water sense pre-rinse spray valve (gallons/minute)
- $Hours_{daily}$ = daily hours of operation specific to facility type (hours)
- $Days_{operation}$ = annual days of pre-rinse spray valve operation. Default value is 365 (days)
- E_{PRSV} = annual energy consumption of the pre-rinse spray valve (kWh or therm)
- $H2O_{hot\ water\ \%}$ = percentage of hot water consumed by the pre-rinse spray valve. Default value is 100%.
- $T_{increase}$ = the increase in water temperature. The average water temperature increase is 75ºF, assuming an average inlet temperature of 60ºF and an outlet water temperature of 135ºF (ºF)
- C_{water} = specific heat of water, 1.0 Btu/pound/ºF
- ρ_{water} = density of water, 8.33 pounds/gallon
- $\eta_{water\ heater}$ = efficiency of the water heater (%)
- conversion = energy conversion
  - 1 KWh = 3,412 Btu
  - 1 therm = 100,000 Btu
- $H2O_{savings}$ = quantity of water saved by replacing conventional model with Energy Star model (gallons)
- $H2O_{conventional}$ = quantity of water consumed by the conventional or "pre-existing" model (gallons)
- $H2O_{WaterSense}$ = quantity of water consumed by the EPA WaterSense model (gallons)
- $E_{savings}$ = quantity of energy saved by replacing conventional model with the EPA WaterSense model (kWh or therms)
- $E_{conventional}$ = quantity of energy consumed by the conventional or "pre-existing" model (kWh or therms)
- $E_{waterSense}$ = quantity of energy consumed by the EPA WaterSense model (kWh or therms)
- $GHG_{electricity}$ = annual GHG emission reductions as a result of electricity savings ($MTCO_2e$)
- $E_{electricity\ savings}$ = quantity of electricity saved by replacing conventional model with Energy Star model (kWh)
- $EF_{electricity}$ = emission factor for electricity (0.000303 $MTCO_2e$/kWh)
- $GHG_{natural\ gas}$ = annual GHG emission reductions as a result of natural gas savings ($MTCO_2e$)

- E natural gas savings = quantity of natural gas saved by replacing conventional model with the EPA WaterSense model (therms)
- EF natural gas = emission factor for natural gas (0.00531 $MTCO_2e$/therm)

Faucets and Showerheads

$$H2O_{annual} = Rate_{flow}\ x\ Minutes_{daily}\ x\ Days_{per\ year}\ x\ Rate_{derate\ flow} \quad \textbf{(Eq. 60)}$$

$$E_{annual} = \frac{H2O_{hot\ water\ \%}\ x\ T_{increase}\ x\ C_{water}\ x\ \rho_{water}}{\eta_{water\ heater}}\ x\ conversion\ x\ H2O_{annual} \quad \textbf{(Eq. 61)}$$

$$H2O_{savings} = H2O_{conventional} - H2O_{retrofit} \quad \textbf{(Eq. 62)}$$

$$E_{savings} = E_{conventional} - E_{retrofit} \quad \textbf{(Eq. 63)}$$

$$GHG_{electricty} = E_{electricity\ savings}\ x\ EF_{electricity} \quad \textbf{(Eq. 64)}$$

$$GHG_{natural\ gas} = E_{natural\ gas\ savings}\ x\ EF_{natural\ gas} \quad \textbf{(Eq. 65)}$$

Where:

- H2O annual = annual water consumption for either the bathroom or kitchen faucet or showerhead(gallons)
- Rate flow = flow rate (conventional or retrofit) for either the bathroom or kitchen faucet or showerhead (gallons/minute)
- Minutes daily = daily minutes of operation specific to the bathroom or kitchen faucet or showerhead (minutes)
- Days per year = annual days of faucet or showerhead use. Default value is 365 (days)
- Rate derate flow = derating flow rate correction factor to reflect actual flow of faucet or showerhead due to line pressure variation, incomplete opening of faucet or showerhead valve, and performance of applicable flow restrictors
- E annual = annual energy consumption of the bathroom or kitchen faucet or showerhead (kWh or therm)
- H2O hot water % = percentage of hot water consumed by the bathroom or kitchen faucet or showerhead. Default value is 50% for faucets and 70% for showerheads.
- T increase = the increase in water temperature. The average water temperature increase is 75ºF assuming an average inlet temperature of 60ºF and an outlet water temperature of 135ºF
- C water = specific heat of water, 1.0 Btu/pound/ºF
- ρ water = density of water, 8.33 pounds/gallon
- η water heater = efficiency of the water heater (%)
- conversion = energy conversion

- o 1 KWh = 3,412 Btu
- o 1 therm = 100,000 Btu

- $H2O_{savings}$ = quantity of water saved by replacing conventional model with the retrofit (gallons)
- $H2O_{conventional}$ = quantity of water consumed by the conventional or “pre-existing” model (gallons)
- $H2O_{retrofit}$ = quantity of water consumed by the faucet retrofit or showerhead retrofit (gallons)
- $E_{savings}$ = quantity of energy saved by replacing conventional model with the retrofit (kWh or therms)
- $E_{conventional}$ = quantity of energy consumed by the conventional or “pre-existing” faucet or showerhead (kWh or therms)
- $E_{retrofit}$ = quantity of energy consumed by the faucet retrofit or showerhead retrofit (kWh or therms)
- $GHG_{electricity}$ = annual GHG emission reductions as a result of electricity savings ($MTCO_2e$)
- $E_{electricity\ savings}$ = quantity of electricity saved by replacing conventional faucet or showerhead with retrofit (kWh)
- $EF_{electricity}$ = emission factor for electricity (0.000303 $MTCO_2e$/kWh)
- $GHG_{natural\ gas}$ = annual GHG emission reductions as a result of natural gas savings ($MTCO_2e$)
- $E_{natural\ gas\ savings}$ = quantity of natural gas saved by replacing conventional faucet or showerhead with retrofit (therms)
- $EF_{natural\ gas}$ = emission factor for natural gas (0.00531 $MTCO_2e$/therm)

Residential Dishwasher

$$Electricity_{machine} = \frac{Electricity_{rated\ consumption}\ x\ (1 - E_{water\ heating\ portion})}{Loads_{default}} \quad \textbf{(Eq. 66)}$$

$$WH_{electricity} = \frac{Electricity_{rated\ consumption}\ x\ E_{water\ heating\ portion}}{Loads_{default}} \quad \textbf{(Eq. 67)}$$

$$WH_{natural\ gas} = \frac{Electricity_{rated\ consumption}\ x\ E_{water\ heating\ portion}}{Loads_{default}\ x\ \eta_{water\ heater}}\ x\ conversion \quad \textbf{(Eq. 68)}$$

$$Electricity_{dishwasher} = \left(Electricity_{machine} + WH_{electricity}\right) x\ Loads_{per\ week}\ x\ weeks_{per\ year} \quad \textbf{(Eq. 69)}$$

$$Gas_{dishwasher} = WH_{natural\ gas}\ x\ Loads_{per\ week}\ x\ weeks_{per\ year} \quad \textbf{(Eq. 70)}$$

$$H2O_{dishwasher} = H2O_{rated\ consumption}\ x\ Loads_{per\ week}\ x\ weeks_{per\ year} \quad \textbf{(Eq. 71)}$$

$$H2O_{savings} = H2O_{conventional} - H2O_{Energy\ Star} \quad \textbf{(Eq. 72)}$$

$$E_{savings} = E_{conventional} - E_{Energy\ Star}$$ **(Eq. 73)**

$$GHG_{electricty} = E_{electricity\ savings}\ x\ EF_{electricity}$$ **(Eq. 74)**

$$GHG_{natural\ gas} = E_{natural\ gas\ savings}\ x\ EF_{natural\ gas}$$ **(Eq. 75)**

Where:

- $\underline{Electricity_{machine}}$ = electrical energy consumed by the dishwasher (kWh)
- $\underline{Electricity_{rated\ consumption}}$ = rated annual electricity consumption of the dishwasher per model type consisting of the machine energy used by the dishwasher during dishwashing cycle, energy used by the water heater to heat the water, and the energy used by the dishwasher while in standby mode. It is based on the DOE test procedure and annual usage of 215 loads per year (kWh/year)
- $\underline{E_{water\ heating\ portion}}$ = portion of hot water energy consumed by the dishwasher (%)
- $\underline{Loads_{default}}$ = default number of annual loads per dishwasher as determined by DOE test procedure (215 loads/year)
- $\underline{WH_{electricity}}$ = hot water energy consumed by the dishwasher with an electric water heater (kWh)
- $\underline{WH_{natural\ gas}}$ = hot water energy consumed by the dishwasher with a natural gas water heater (therms)
- $\underline{\eta_{water\ heater}}$ = efficiency of the water heater (%)
- conversion = energy conversion
  - o 1 KWh = 3,412 Btu
  - o 1 therm = 100,000 Btu
- $\underline{Electricity_{dishwasher}}$ = annual electricity consumed by the dishwasher (kWh)
- $\underline{Loads_{per\ week}}$ = estimated dishwasher loads per week
- $\underline{weeks_{per\ year}}$ = estimated weeks of dishwasher usage
- $\underline{Gas_{dishwasher}}$ = annual natural gas consumed by the dishwasher (therms)
- $\underline{H2O_{dishwasher}}$ = annual water consumed by the dishwasher (gallons)
- $\underline{H2O_{rated\ consumption}}$ = estimated per cycle water consumption per model type under typical conditions as measured by DOE test procedure (gallons/cycle)
- $\underline{H2O_{savings}}$ = quantity of water saved by replacing conventional model with Energy Star model (gallons)
- $\underline{H2O_{conventional}}$ = quantity of water consumed by the conventional or "pre-existing" model (gallons)
- $\underline{H2O_{Energy\ Star}}$ = quantity of water consumed by the Energy Star model (gallons)
- $\underline{E_{savings}}$ = quantity of energy saved by replacing conventional model with Energy Star model (kWh or therms)
- $\underline{E_{conventional}}$ = quantity of energy consumed by the conventional or "pre-existing" model (kWh or therms)

- $E_{Energy\ Star}$ = quantity of energy consumed by the Energy Star model (kWh or therms)
- $GHG_{electricity}$ = annual GHG emission reductions as a result of electricity savings ($MTCO_2e$)
- $E_{electricity\ savings}$ = quantity of electricity saved by replacing conventional model with Energy Star model (kWh)
- $EF_{electricity}$ = emission factor for electricity (0.000303 $MTCO_2e$/kWh)
- $GHG_{natural\ gas}$ = annual GHG emission reductions as a result of natural gas savings ($MTCO_2e$)
- $E_{natural\ gas\ savings}$ = quantity of natural gas saved by replacing conventional model with Energy Star model (therms)
- $EF_{natural\ gas}$ = emission factor for natural gas (0.00531 $MTCO_2e$/therm)

Residential Clothes Washer

$$Electricity_{rated\ consumption} = Electricity_{rated-DOE}\ x\ \frac{Loads_{per\ year}}{Loads_{reference}} \quad \textbf{(Eq. 76)}$$

$$Electricity_{washer\ total} = \frac{capacity}{IMEF}\ x\ Loads_{per\ year} \quad \textbf{(Eq. 77)}$$

$$Electricity_{machine} = Electricity_{machine\ portion}\ x\ Electricity_{rated\ consumption} \quad \textbf{(Eq. 78)}$$

$$WH_{electricity} = Electricity_{water\ heating\ portion}\ x\ Electricity_{rated\ consumption} \quad \textbf{(Eq. 79)}$$

$$WH_{natural\ gas} = \frac{Electricity_{water\ heating\ portion}\ x\ Electricity_{rated\ consumption}}{\eta_{gas\ water\ heater}}\ x\ conversion \quad \textbf{(Eq. 80)}$$

$$Dryer_{electricity} = (Electricity_{washer\ total} - Electricity_{rated\ consumption} - Electricity_{low-power\ mode})\ x\ \frac{\%_{loads\ dried}}{DUF}\ x\ DU \quad \textbf{(Eq. 81)}$$

$$Dryer_{natural\ gas} = (Electricity_{washer\ total} - Electricity_{rated\ consumption})\ x\ \frac{\%_{loads\ dried}}{DUF}\ x\ DU\ x\ GCF \quad \textbf{(Eq. 82)}$$

$$E_{electricity} = E_{machine\ electrical} + WH_{electricity} + Dryer_{electricity} + Electricity_{low-power\ mode} \quad \textbf{(Eq. 83)}$$

$$E_{natural\ gas} = WH_{natural\ gas} + Dryer_{natural\ gas} \quad \textbf{(Eq. 84)}$$

$$H2O_{annual} = IWF\ x\ capacity\ x\ Loads_{per\ week}\ x\ weeks_{per\ year} \quad \textbf{(Eq. 85)}$$

$$H2O_{savings} = H2O_{conventional} - H2O_{Energy\ Star} \quad \textbf{(Eq. 86)}$$

$$E_{savings} = E_{conventional} - E_{Energy\ Star} \quad \textbf{(Eq. 87)}$$

$$GHG_{electricty} = E_{electricity\ savings}\ x\ EF_{electricity} \quad \textbf{(Eq. 88)}$$

$$GHG_{natural\ gas} = E_{natural\ gas\ savings}\ x\ EF_{natural\ gas} \quad \textbf{(Eq. 89)}$$

Where:

- Electricity $_{rated\ consumption}$ = estimated annual rated electricity consumption of the clothes washer based on the DOE rated electricity consumption undergoing the DOE test procedure and the ratio of the estimated loads washed per year in the CEC program residence against a reference load of 392 loads per year as determined by DOE (kWh/year)
- Electricity $_{rated\text{-}DOE}$ = estimated annual electricity consumption of the clothes washer under typical conditions consisting of the electricity consumed by the clothes washer and the energy needed to heat the water used by the clothes washer with an electric water heater. The electricity rated consumption is based on 392 loads per year as referenced by the DOE test procedure (kWh/year)
- Loads $_{per\ year}$ = number of loads per year per clothes washer used in single family/multi-family residential applications
- Loads $_{reference}$ = number (392) of loads used in the DOE test procedure as part of the uniform test method for measuring the energy consumption of clothes washers.
- Electricity $_{washer\ total}$ = annual electricity consumption of the clothes washer, based on an electric water heater, consisting of the electricity consumed by the clothes washer, hot water energy consumption, and the dryer energy required for the removal of the remaining moisture in the wash load with an electric dryer (kWh/year)
- capacity = tub capacity of clothes washer as measured by the DOE test procedure (cubic feet, ft^3)
- IMEF = integrated modified energy factor. The energy metric for residential clothes washers, where, the higher the metric, the more efficient the clothes washer (ft^3/kWh)

  $$IMEF = \frac{capacity}{M+E+D+L}$$

  Where:
  - M = Electricity $_{machine}$
  - E = WH $_{electricity}$
  - D = Dryer $_{electricity}$
  - L = low-power mode energy consumption
- Electricity $_{machine}$ = electrical energy consumed by the clothes washer during wash mode (kWh)
- Electricity $_{machine\ portion}$ = portion of electricity consumed by the clothes washer during wash mode as compared to the electricity (hot water energy) consumed by the washer machine with an electric water heater (%)

- WH $_{electricity}$ = electrical hot water energy consumed by the clothes washer with an electric water heater (kWh)
- Electricity $_{water\ heating\ portion}$ = portion of electrical hot water energy consumed by the clothes washer with an electric water heater as compared to the electricity consumed by the clothes washer during wash mode (%)
- $\eta_{gas\ water\ heater}$ = natural gas water heater efficiency (%)
- conversion = energy conversion
  - 1 KWh = 3,412 Btu
  - 1 therm = 100,000 Btu
- Dryer $_{electricity}$ = electricity consumed by an electric dryer for the removal of the remaining moisture from the wash load (kWh)
- Electricity $_{low\text{-}power\ mode}$ = electricity consumed during washer machine in low-power mode (kWh)
- % $_{loads\ dried}$ = percentage of wash loads dried in a clothes dryer as determined by the calculator user. Default is 100%.
- DUF = dryer usage factor, percentage of wash loads dried in a clothes dryer (0.84) as determined by the DOE test procedure
- DU = dryer usage in buildings or households with both a clothes washer and clothes dryer (0.95)
- Dryer $_{natural\ gas}$ = energy consumed by the natural gas dryer for the removal of the remaining moisture from the wash load (therms)
- GCF = natural gas correction factor to account for the additional energy required by a gas dryer to dry clothes relative to an electric dryer (1.12)
- E $_{electricity}$ = annual quantity electricity consumed by either the conventional or Energy Star clothes washer (kWh)
- E $_{natural\ gas}$ = annual quantity of natural gas consumed by either the conventional or Energy Star clothes washer (therms)
- H2O $_{annual}$ = annual quantity of water consumed by either the conventional or Energy Star clothes washer (gallons)
- IWF = integrated water factor, is the metric for the water performance of the residential clothes washer. The lower the IWF, the more efficient the clothes washer (gallons/ft^3)

  $$IWF = \frac{Q_A}{capacity}$$

  Where:
  - Q_A = total weighted per-cycle water consumption (gallons)
- Loads $_{per\ week}$ = number of loads per week per clothes washer used in multi-family and residential applications
- weeks $_{per\ year}$ = number of weeks throughout the year the clothes washer is used. Default value of 52 (weeks)
- H2O $_{savings}$ = quantity of water saved by replacing conventional model with Energy Star model (gallons)
- H2O $_{conventional}$ = quantity of water consumed by the conventional or “pre-existing” model (gallons)

- H2O $_{Energy\ Star}$ = quantity of water consumed by the Energy Star model (gallons)
- E $_{savings}$ = quantity of energy saved by replacing conventional model with Energy Star model (kWh + therm or kWh)
- E $_{conventional}$ = quantity of energy consumed by the conventional or “pre-existing” model (kWh + therm or kWh)
- E $_{Energy\ Star}$ = quantity of energy consumed by the Energy Star model (kWh + therm or kWh)
- GHG $_{electricity}$ = annual GHG emission reductions as a result of electricity savings ($MTCO_2e$)
- E $_{electricity\ savings}$ = quantity of electricity saved by replacing conventional model with Energy Star model (kWh)
- EF $_{electricity}$ = emission factor for electricity (0.000303 $MTCO_2e$/kWh)
- GHG $_{natural\ gas}$ = annual GHG emission reductions as a result of natural gas savings ($MTCO_2e$)
- E $_{natural\ gas\ savings}$ = quantity of natural gas saved by replacing conventional model with Energy Star model (therms)
- EF $_{natural\ gas}$ = emission factor for natural gas (0.00531 $MTCO_2e$/therm)