California Air Resources Board

Greenhouse Gas Quantification Methodology for the Department of Community Services and Development Low-Income Weatherization Program Single-Family Energy Efficiency & Solar Photovoltaics

Greenhouse Gas Reduction Fund
Fiscal Year 2015-16

November 14, 2016

Table of Contents

Section A. Introduction

The goal of California Climate Investments is to reduce greenhouse gas (GHG) emissions and further the purposes of the Global Warming Solutions Act of 2006, known as Assembly Bill (AB) 32. The California Air Resources Board (ARB) is responsible for providing the quantification methodology to estimate GHG reduction estimates and other benefits from projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF). ARB develops these methodologies based on the project types eligible for funding by each administering agency as reflected in the program Expenditure Records available at: https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/expenditurerecords.htm. ARB staff 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.

For the Department of Community Services and Development (CSD) Low-Income Weatherization Program (LIWP), ARB staff, in consultation with CSD, developed this fiscal year (FY) 2015-16 quantification methodology to provide methods to estimate direct, on-site energy savings in electricity (kWh), natural gas (therms), and other heating fuel types (mmBtu) from energy efficiency and renewable energy projects (Sections B and C). In addition, this quantification methodology was developed to provide instructions for documenting and supporting the estimate (Section D), and to outline the process for tracking and reporting GHG and other benefits once a project is funded (Section E).

This methodology uses calculations to estimate GHG emission reductions from energy savings associated with the implementation of LIWP projects. CSD will report the total Program GHG emission reductions estimated using this methodology.

LIWP Project Types

The energy efficiency component of LIWP is the implementation of appropriate upgrades and repairs to improve the overall energy efficiency of a dwelling. An energy efficient dwelling in California will reduce GHG emissions by reducing electricity and heating fuel consumption. The energy efficiency quantification methodologies described in this document pertain only to single-family dwellings. Single-family dwellings are defined in the CSD LIWP Guidelines.[1]

LIWP will reduce GHG emissions through projects that implement energy efficiency or renewable energy measures. CSD has identified three project types for single-family homes:

1. Energy Efficiency measures, which include upgrades and retrofits that reduce energy consumption;

[1] Low-Income Weatherization Program: Draft 15-16 Program Guidelines: Single Family Energy Efficiency and Solar PV. Available at: http://www.csd.ca.gov/Resources/ProgramGuidelines.aspx

2. Solar Water Heater (SWH), which uses a solar thermal collector to deliver hot water, thereby reducing the need to use electricity or heating fuel; and
3. Solar Photovoltaics (PV), which use solar panels to provide electricity, thereby reducing grid-based electricity use.

Eligible households may have one or more project types installed based on evaluations conducted by LIWP Providers.

Methodology Development

ARB and CSD developed this quantification methodology consistent with the guiding implementation principles of California Climate Investments, including ensuring transparency and accountability.[2] ARB and CSD developed this quantification methodology through a public process to be used to estimate the outcomes of proposed projects, inform project selection, and track results of funded projects. The implementing principles ensure that the methodology will:

- Apply at the project-level;
- Align with the project types proposed for funding with GGRF monies;
- Provide uniform methods to be applied statewide, and be accessible by all LIWP Administrators/Providers;
- Use existing and proven methods;
- Use project-level data, where available and appropriate; and
- Result in GHG emissions-reduction estimates that are conservative and supported by empirical literature.

ARB reviewed peer-reviewed literature and consulted with experts, as needed, to determine methods appropriate for the LIWP project types. ARB also consulted with CSD to determine project-level inputs available. The methods were developed to provide estimates that are as accurate as possible while remaining conservative with data readily available at the project level.

CSD will quantify and report GHG emission reduction estimates using two approaches:

1. Awarded Funds. Estimates will be quantified using the methods described in Section B upon contracting with LIWP Providers.
2. Implemented Projects. Estimates will be quantified using the methods described in Section C as projects are implemented and measures are installed.

ARB released a draft FY 2015-16 quantification methodology for public comment in October 2016, prior to finalizing this document.

[2] 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.

Program Assistance

CSD staff will ensure that the quantification methods described in this document are properly applied to estimate the GHG emission reductions for the project types.

- Questions on this quantification document should be sent to GGRFProgram@arb.ca.gov.
- Questions not related to this quantification document, but pertaining to LIWP should be sent to www.csd.ca.gov/ContactUs.aspx.
- For more information on ARB's efforts to support implementation of GGRF investments, see: www.arb.ca.gov/auctionproceeds.

Section B. Greenhouse Gas Quantification Methodology for Awarded Funds

The quantification methodology in this section describes how CSD will estimate the GHG emission reductions based on contracts executed with LIWP Providers for the current FY funding, prior to project installation (implementation). The GHG emission reduction estimates rely on historical data and the anticipated number, type, and location of projects to be implemented with FY 2015-16 funding based on LIWP Provider location and contract amount. This approach is a "top-down" estimate, which is reported at the Program level and is refined as LIWP Providers complete contracts and provide project-specific information (described in Section C). The methods are described below by project type.

Energy Efficiency

Energy efficiency GHG reduction estimates are based on the projected number of dwellings anticipated to receive energy efficiency measures and the average annual GHG emission reductions achieved per dwelling. The average annual GHG emission reduction value is based on historical data, as estimated by CSD, that reflects a number of different measure packages installed per dwelling across varying climate zones and different heating fuels that are used in a dwelling. Note that programmatic objectives for energy efficiency measure packages installed may change and the historical average applied in this methodology reflects historical programmatic objectives.

For the single family component, the historical average GHG emission reduction factor is 0.46 metric tons of carbon dioxide equivalents ($MTCO_2e$) per dwelling.[3] The following equation is used to calculate the GHG emission reduction estimates of awarded funds for the energy efficiency sub-program:

[3] The GHG emission reduction factor per dwelling is based on historical data collected by CSD for projects implemented during FY 2014-15. Note that programmatic objectives for energy efficiency measure packages installed may change and the historical average applied in this methodology reflects historical programmatic objectives.

$$GHG_{energy\ efficiency} = Dwellings_{estimate}\ x\ GHG_{dwelling}\ x\ EUL_{average}$$ **(Eq. 1)**

Where:

- GHG $_{\text{energy efficiency}}$ = GHG emission reduction estimate of awarded funds for the energy efficiency component ($MTCO_2e$)
- Dwellings $_{\text{estimate}}$ = anticipated number of dwellings to receive energy efficiency measures (dwelling)
- GHG $_{\text{dwelling}}$ = statewide average annual GHG emission reduction per dwelling estimate based on historical data collected on implemented energy efficiency projects ($MTCO_2e$ per dwelling per year)
- EUL $_{\text{average}}$ = average effective useful life of all measures installed (15 years)[4]

Solar Water Heaters

SWH GHG reduction estimates are based on the average annual GHG emission reductions per system and the anticipated number of systems projected for installation. The following equation is used to calculate the GHG emission reduction estimates of awarded funds for SWHs:

$$GHG_{SWH} = [\sum_{n=1}^{n=x}[1-(n)(R_{degradation})](GHG_{per\ system})]\ x\ SWH_{total}$$ **(Eq. 2)**

Where:

- GHG $_{\text{SWH}}$ = total GHG emission reduction estimate of awarded funds for the SWH component ($MTCO_2e$)
- n = year
- x = estimated useful life of SWH systems (25 years)[5]
- R $_{\text{degradation}}$ = rate of system degradation (0.5% per year)[6]
- GHG $_{\text{per system}}$ = statewide annual average GHG emission reduction per system derived from CSI Thermal Calculator assumptions[7]
- SWH $_{\text{total}}$ = anticipated number of SWH systems to be installed

[4] The average effective useful life of 15 years is the average useful life of measure packages installed as part of LIWP.

[5] California Solar Initiative Thermal Program Handbook Rev 18.1.0. Available at: http://www.gosolarcalifornia.ca.gov/documents/CSI-Thermal_Handbook.pdf

[6] The estimated rate of system degradation was obtained from NREL Technical Report (2011). "Break-even Cost for Residential Solar Water Heating in the United States: Key Drivers and Sensitivities." Available at: http://www.nrel.gov/docs/fy11osti/48986.pdf. Accessed on September 12, 2016.

[7] The average annual GHG emission reduction per system is 0.82 $MTCO_2e$. This value was derived from historical data collected by CSD on SWH systems installed as part of LIWP during FY 2014-15 and reflects systems installed across various climate zones.

Solar Photovoltaics

Solar photovoltaics (PV) GHG emission reduction estimates are based on the projected solar capacity that can be installed. The estimated installed capacity results from historical programmatic data collected on the installation of solar PV systems. The following equation is used to calculate the GHG emission reduction estimates of awarded funds for solar PV:

$$GHG_{solar\ PV} = \sum_{n=1}^{n=x} C\left[1-(n)\left(R_{degradation}\right)\right](CF)\left(EF_{electricity}\right)(8760) \quad \textbf{(Eq. 3)}$$

Where:

- GHG $_{\text{solar PV}}$ = total GHG emission reduction estimate of awarded funds for solar PV ($MTCO_2e$)
- n = year
- x = estimated useful life of SWH systems (30 years)[8]
- C = estimated solar PV capacity for installation (MW)
- R $_{\text{degradation}}$ = rate of system degradation (0.5% per year)[9]
- CF = capacity factor, which is the actual output/maximum output of the solar PV system. Uses an average CA capacity factor of 0.175[10]
- EF $_{\text{electricity}}$ = emission factor for electricity ($MTCO_2e$ per MWh)[11]
- 8760 = number of hours in a year (hours per year)

[8] Life Cycle Greenhouse Gas Emissions from Solar Photovoltaics, NREL fact sheet. Available at: http://www.nrel.gov/docs/fy13osti/56487.pdf. Accessed on September 12, 2016.
[9] The estimated rate of system degradation was obtained from NREL Technical Report (2012). "Photovoltaic Degradation Rates. Abstract". Available at: http://www.nrel.gov/docs/fy12osti/51664.pdf. Accessed on September 12, 2016.
[10] Used a California average capacity factor based on results from a Draft CEC report: Cost-effectiveness of rooftop photovoltaic systems for consideration in California's building energy efficiency standards (2013). Available at: http://www.energy.ca.gov/2013publications/CEC-400-2013-005/CEC-400-2013-005-D.pdf. Accessed on September 30, 2016.
[11] See Appendix A

Section C. Greenhouse Gas Quantification Methodology for Implemented Projects

The quantification methodology in this section describes how CSD will refine the emission reduction estimates from Section B as LIWP Providers install (implement) projects and report post-project-specific information. The applicable tools used to support this methodology are listed by project type in Table 1 and are described in the following sections. Quantifying project energy savings will vary by dwelling due to variations in dwelling type, location, and the number and types of measures installed. For all installed measures funded by GGRF, LIWP Providers submit monthly reports that document dwelling specific characteristics such as location data, heating fuel type, and details on each installed measure. CSD will use this data to identify climate-zone-specific energy savings for each measure from sources outlined in Appendix B. CSD will calculate the estimated GHG emission reductions for each installed measure by applying the appropriate emission factor(s) described in Appendix A.

Table 1: Summary of LIWP Project Types and Applicable Tools

Project Type	Tools	
Energy Efficiency	Basic LIWP Measure Package	Deemed Savings - Database for Energy Efficient Resources (DEER)[12] and other utility methodologies[13]
	Enhanced LIWP Measure Package	Deemed Savings - Energy Assessment Tools[14] - or - DEER and other utility methodologies[13]
Solar Water Heater (SWH)	CSI Solar Thermal Calculator	
Solar Photovoltaics (PV)	NREL PVWatts Calculator	

[12] DEER. Available online at: http://www.deeresources.com/. Accessed on September 12, 2016.
[13] See Appendix B.
[14] List of approved CEC energy audit software. Available at: http://www.energy.ca.gov/title24/2016standards/2016_computer_prog_list.html.
List of approved EUC energy audit tools. Available at: http://homeupgrade.org/2335-2/. Both accessed on September 12, 2016.

Energy Efficiency

The "Project Case"

The "project case" represents the estimated GHG emission reductions expected to occur for a project after the energy efficiency measures are implemented. The first step in calculating the "project case" is conducting a home energy assessment. The assessment evaluates the dwelling's enclosure, or "thermal boundary,"[15] and the interactive effects of all energy related systems in the dwelling to identify potential sources of inefficiencies. LIWP Providers conduct the home energy assessment to generate a list of recommended measures that can improve the energy efficiency of the dwelling, and subsequently reduce GHG emissions. Based on the results of the assessment, the LIWP Providers will determine which measures from the following packages to install:

Basic LIWP Measure Package – Utilizes a specific list of allowable measures, identified in the CSD LIWP Guidelines.

Enhanced LIWP Measure Package – Enhanced measures may be available based on home energy assessment. Measures that require an energy audit assessment are listed in CSD's LIWP Guidelines. The pool of eligible measures for the Enhanced LIWP Measure Package is larger than the list used in the Basic LIWP Measure Package, as described in CSD's LIWP Guidelines.

Basic LIWP Measure Package

For the Basic LIWP Measure Package, CSD will quantify energy savings from projects using a deemed savings approach utilizing DEER and other methodologies or energy savings results described in utility energy efficiency program evaluation reports and resource manuals.

Deemed savings is an approach to estimating energy and demand savings, usually used with programs targeting simpler efficiency measures with well-known and consistent performance characteristics. This method involves multiplying the number of installed measures by an estimated (or deemed) savings per measure, which is derived from historical evaluations.[16] DEER is a California Energy Commission (CEC) and California Public Utilities Commission (CPUC) sponsored database. DEER is designed to provide well-documented estimates of energy and peak demand savings values, measure costs, and effective useful life (EUL). DEER provides "ex ante"[17] estimates of the energy-savings potential for energy-efficient technologies and measures in residential and nonresidential applications.

---

[15] The thermal boundary is what separates the dwelling's conditioned space from its unconditioned space.
[16] EPA deemed savings definition available online at: https://www.epa.gov/statelocalclimate/calculating-energy-savings. Accessed on September 12, 2016.
[17] Ex ante is Latin for "beforehand." The ex ante process estimates the potential energy savings for an energy efficient measure before installation based on predictions of typical operating conditions and baseline usage.

DEER provides the necessary data elements to apply a deemed savings approach and identify the annual energy savings associated with each specific measure by building location, building vintage, and building type. DEER provides a list of measures organized by a specific measure ID, measure description, and energy impact values for each end use category, such as building envelope, appliance or plug load, and heating, ventilation and air conditioning (HVAC), among others. Once the specific measure is selected, the energy impact values for the measure can be determined by identifying the appropriate building location (climate zone), building vintage, and building type (single-family or small multi-family dwellings only). The summation of the measures and associated energy impact values is the total estimated energy savings for all home improvements.

DEER provides energy impact values categorized by "whole building" and "direct end-use." The "whole building" energy impact values account for the HVAC interactive effects associated with measure installation(s), such as lighting, whereas the "direct end-use" energy impact values are the direct energy impacts of the specific measure installed.

GHG emission reductions from calculated energy savings utilizing the deemed savings approach will be estimated as follows:

$$GHG_{annual\ reductions\ per\ measure} = (DS_{electricity}\ x\ EF_{electricity}) + (DS_{fuel}\ x\ EF_{fuel}) \quad \textbf{(Eq. 4)}$$

$$GHG_{EUL\ per\ measure} = (GHG_{anual\ reductions\ per\ measure}\ x\ EUL_{measure}) \quad \textbf{(Eq. 5)}$$

$$GHG_{dwelling} = \sum_{i=1}^{i=x} GHG_{EUL\ per\ measure,i} \quad \textbf{(Eq. 6)}$$

Where:

- $GHG_{\text{annual reductions per measure}}$ = estimated annual GHG emission reductions per efficiency measure installed ($MTCO_2e$ per year)
- $DS_{\text{electricity}}$ = estimated annual deemed savings of electricity for a specific measure using "whole building" energy impact value (kWh per year)
- $EF_{\text{electricity}}$ = emission factor for electricity ($MTCO_2e$ per kWh)[18]
- DS_{fuel} = estimated annual deemed savings of heating fuel for a specific measure using "whole building" energy impact value (therms or mmBtu per year)
- EF_{fuel} = emission factor for heating fuel ($MTCO_2e$ per therm or mmBtu)[19]
- $GHG_{\text{EUL per measure}}$ = GHG emission reductions per measure installed over the effective useful life of the measure ($MTCO_2e$)
- EUL_{measure} = effective useful life; for energy efficiency measures the EUL is provided by DEER or other applicable sources (years)
- GHG_{dwelling} = total project GHG emissions reduced per dwelling ($MTCO_2e$)
- i = measure installed (e.g., windows, insulation, etc.)

[18] See Appendix A.

Enhanced LIWP Measure Package

For the Enhanced LIWP Measure package, CSD will quantify energy savings from projects using an energy assessment tool or other approach (e.g., DEER, energy savings results described in utility energy efficiency program evaluation reports and resource manuals). The use of an energy assessment tool is dependent on the potential measures that are feasible for a particular project. For projects that do not require the use of an energy assessment tool, energy savings are quantified using a deemed savings methodology described in the previous section for the Basic LIWP Measure Package and Equations 4 – 6.

Projects requiring use of an energy assessment tool are described in CSD's LIWP Guidelines. Energy assessment tools are used for a "whole building" analysis to determine the energy performance of the dwelling and identify opportunities for energy efficiency improvements. Energy assessment tools utilize specialized software to determine the dwelling energy load and estimate energy consumption from data points on the geometric characteristics, thermal boundary, location, number of occupants, and energy systems.

There are many energy assessment tools in the marketplace. These tools may vary considerably in how they collect and analyze dwelling characteristics and generate energy efficiency improvement recommendations.[19] LIWP uses energy assessment software tools approved by the CEC or Energy Upgrade California (EUC) for compliance with energy efficiency programs.

Total GHG emission reduction estimation depends on the capabilities of the energy assessment tool used. If the energy assessment tool is able to determine the annual energy savings for each measure installed, then Equations 4 – 6 above should be used for calculating total project GHG emission reductions per dwelling. Conversely, if the energy assessment tool only provides the total annual energy savings for all measures installed as an aggregate value, then Equations 7 – 10 below should be used for calculating total project GHG emission reductions per dwelling.

After LIWP Providers submit energy savings data, CSD will quantify estimated GHG emission reductions as follows:

$$GHG_{electricity} = EA_{electricity}\ x\ EF_{electricity} \quad \textbf{(Eq. 7)}$$

$$GHG_{fuel} = EA_{fuel}\ x\ EF_{fuel} \quad \textbf{(Eq. 8)}$$

$$GHG_{total} = GHG_{electricity} + GHG_{fuel} \quad \textbf{(Eq. 9)}$$

$$GHG_{dwelling} = GHG_{total}\ x\ EUL_{average} \quad \textbf{(Eq. 10)}$$

[19] Review of selected home energy auditing tools, DOE. (2010, November 2). Available at http://apps1.eere.energy.gov/buildings/publications/pdfs/homescore/auditing_tool_review.pdf. Accessed on September 12, 2016.

Where:

- $GHG_{electricity}$ = estimated annual GHG emissions reduced from electricity ($MTCO_2e$)
- $EA_{electricity}$ = estimated annual energy savings from electricity for all measures installed (kWh)
- $EF_{electricity}$ = emission factor for electricity ($MTCO_2e$ per kWh)[20]
- GHG_{fuel} = estimated annual GHG emissions reduced from heating fuel ($MTCO_2e$)
- EA_{fuel} = estimated annual energy assessment savings from heating fuel type of all measures installed (therms or mmBtu)
- EF_{fuel} = emission factor for heating fuel type ($MTCO_2e$ per therm or mmBtu)[20]
- $GHG_{dwelling}$ = total project GHG emissions reduced per dwelling ($MTCO_2e$)
- GHG_{total} = sum of annual GHG emissions reduced from electricity and heating fuel ($MTCO_2e$)
- $EUL_{average}$ = estimated average useful life for measures installed (years) [21]

Solar Water Heaters

Solar water heaters (SWH) use radiant heat from the sun to heat either water or a heat-transfer fluid in a roof-mounted collector. SWH systems typically provide 60 percent of the heat for hot water needed by an end-user, with the remainder provided by a back-up water heater powered by natural gas or electricity. The most common applications for SWH systems are for direct hot water uses in the home, such as showers, dishwashers, and clothes washing machines.

The "Project Case"

The "project case" represents the estimated GHG emission reductions expected to occur after SWH installation. The California Solar Initiative (CSI) solar thermal calculator[22] for Standard-300 systems is the methodology used for estimating the project case for SWH projects. The CSI solar thermal calculator is an online calculation tool that provides an estimate of the energy displacement for SWH systems based on performance of the SWH system, location, and system design. The CSI solar thermal calculator estimates an energy savings value for Solar Rating & Certification Corporation (SRCC) OG-300 rated systems and provides annual system savings estimates for locations in California.

Below are the CSI solar thermal calculator inputs:

- SWH Standard 300 system type
- Site zip code
- Backup water heater type

[20] See Appendix A.
[21] To determine the average EUL, use the DEER database to identify EULs for each measure installed and calculate the overall average.
[22] CSI Thermal Program Incentive Calculator for Standard-300 Systems is available at https://www.csithermal.com/calculator/. Accessed on September 12, 2016.

- Azimuth
- Tilt
- Annual average access – (average annual percentage of access to sun from this solar array from 10:00 am – 3:00 pm PST[23])
- Gas utility service provider
- Electric utility service provider

The SWH annual system savings results (kWh or therms) from the CSI solar thermal calculator will be used to estimate the total GHG emission reductions ($MTCO_2e$) as follows:

$$GHG_{SWH} = \sum_{n=1}^{n=x} \left[1 - (n)\left(R_{degradation}\right)\right]\left(SWH_{savings}\right)(EF) \quad \textbf{(Eq. 11)}$$

Where:

- GHG_{SWH} = total GHG emissions reduced from SWH system ($MTCO_2e$)
- n = year
- x = useful life (25 years)[24]
- $R_{degradation}$ = rate of system degradation (0.5% per year)[25]
- $SWH_{savings}$ = estimated annual system savings from CSI solar thermal calculator (kWh or therms per year)
- EF = emission factor; electricity ($MTCO_2e$ per kWh) or natural gas ($MTCO_2e$ per therm)[26]

Solar Photovoltaics

Solar photovoltaics (PV) are a renewable energy system that generates electricity directly from sunlight via an electronic process that occurs in semiconductors. Electrons in semiconductors are released by solar energy and can be induced to travel through an electrical circuit, powering electrical devices, homes, buildings, or sending the electricity to the electrical grid.[27] Solar PV is conventionally installed on rooftops to provide electricity to a dwelling or can be installed as a ground-mounted "solar farm" to provide electricity to a community.

[23] Refer to section 2.6 of the CSI solar thermal handbook for more information. Available at http://www.gosolarcalifornia.ca.gov/documents/CSI-Thermal_Handbook.pdf. Accessed on September 12, 2016.
[24] California Solar Initiative Thermal Program Handbook Rev 18.1.0. Available at: http://www.gosolarcalifornia.ca.gov/documents/CSI-Thermal_Handbook.pdf
[25] The estimated rate of system degradation was obtained from the NRELTechnical Report (2011). "Break-even Cost for Residential Solar Water Heating in the United States: Key Drivers and Sensitivities. Section 2.3". Available at: http://www.nrel.gov/docs/fy11osti/48986.pdf. Accessed on September 12, 2016.
[26] See Appendix A.
[27] The electrical grid is an interconnected network for delivering electricity from suppliers to consumers.

The "Project Case"

The "project case" represents the estimated GHG emission reductions expected to occur after solar PV installation on a dwelling rooftop. Several solar PV calculators have been developed that identify annual solar PV output based on specific system type, inverter type, system size, location, etc. The National Renewable Energy Laboratory (NREL) PVWatts calculator[28] is the methodology that will be used to estimate electricity savings from LIWP solar PV installations.

The NREL PVWatts Calculator is a web-based application that estimates the electricity production of a grid-connected roof- or ground-mounted PV system based on simple inputs. CSD enters information about the system location, basic design parameters, and system economics. PVWatts calculates estimated values for the system's annual and monthly electricity production, and for the monetary value of the electricity.

The PVWatts calculator inputs are as follows:

- Location
- DC system size (kW)
- Module type
- Array type
- System losses (%)
- Tilt (°)
- Azimuth (°)
- "Loss Calculator," which includes the following (as a percent, %):
    - Soiling
    - Shading
    - Snow
    - Mismatch
    - Wiring
    - Connections
    - Light induced degradation
    - Nameplate rating
    - Age
    - Availability
- "Advanced Parameters", which includes the following:
    - Direct current (DC) to alternating current (AC) size ratio
    - Inverter efficiency
    - Ground coverage ratio

The solar PV annual generation results (kWh) from the PVWatts calculator will be used to estimate the total GHG emission reductions ($MTCO_2e$) as follows:

[28] National Renewable Energy Laboratory PVWatts Calculator. Available at http://pvwatts.nrel.gov/. Accessed on September 12,2016.

$$GHG_{PV} = \sum_{n=1}^{n=x} \left[1 - (n)\left(R_{degradation}\right)\right]\left(PV_{production}\right)\left(EF_{electricity}\right) \quad \textbf{(Eq. 12)}$$

Where:

- GHG $_{PV}$ = total GHG emissions reduced from solar PV system ($MTCO_2e$)
- n = year
- x = useful life (30 years)[29]
- R $_{degradation}$ = rate of system degradation (0.5% per year)[30]
- PV $_{production}$ = estimated annual kWh generated by solar PV calculator (kWh per year)
- EF $_{electricity}$ = emission factor for electricity ($MTCO_2e$ per kWh)[31]

[29] Life Cycle Greenhouse Gas Emissions from Solar Photovoltaics, NREL fact sheet. Available at: http://www.nrel.gov/docs/fy13osti/56487.pdf. Accessed on September 12, 2016.
[30] The estimated rate of system degradation was obtained from NREL Technical Report (2012). "Photovoltaic Degradation Rates. Abstract". Available at: http://www.nrel.gov/docs/fy12osti/51664.pdf. Accessed on September 12, 2016.
[31] See Appendix A.

Section D. Documentation

CSD must report Total Program GHG Emission Reductions for both awarded funds and implemented projects. For awarded funds, CSD reports the sum total of each of the project type GHG Emission Reductions as calculated in Section B.

$$\begin{aligned} &Total\ Program\ GHG\ Emission\ Reductions\ in\ MTCO_2e \\ &= \sum GHG_{dwelling}\ (from\ energy\ efficiency) \\ &+ \sum GHG_{SWH}\ (from\ solar\ water\ heaters) \\ &+ \sum GHG_{PV}\ (from\ solar\ PV) \end{aligned} \quad \textbf{(Eq. 13)}$$

For implemented projects, CSD must report the GHG emission reductions by project type and by census tract as calculated in Section C. CSD must also report the following metric per project type and per dwelling by census tract:

$$\frac{Total\ Program\ GHG\ Emission\ Reduction\ \ (Metric\ Tons\ of\ CO_2e)}{Total\ GGRF\ Funds\ Implemented\ (\$)}$$

Requirements for LIWP implementation and reporting are subject to change based on future revisions that would apply to all agencies administering California Climate Investment programs (e.g., legislation, updates to ARB's Funding Guidelines for Agencies Administering California Climate Investments (Funding Guidelines).[32] Implementing agencies/providers should note that additional reporting may be required or modified for some types of projects based on the evolving needs of California Climate Investments. 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.

Supporting Documentation

CSD and LIWP Providers are required to retain documentation that is sufficient to allow all quantification calculations to be reviewed and replicated.

Supporting documentation must include, at a minimum:

- Contact information for the person who can answer project specific questions on the quantification calculations.
- Project specific data inputs for energy efficiency, SWH, and solar PV;
- Estimated energy savings and GHG emission reductions per dwelling and by project type per dwelling.

[32] 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. Accessed on September 12, 2016.

Section E. Reporting after Funding Award

Accountability and transparency are essential elements for all GGRF California Climate Investment projects. As described in ARB's Funding Guidelines for Agencies that Administer California Climate Investments (Funding Guidelines),[33] each administering agency is required to track and report on the benefits of the California Climate Investments funded under their program(s). Each project funded by the GGRF is expected to provide quantifiable GHG emission reductions. The previous sections of this document provide the methods and tools to estimate the GHG emission reductions of projects based on project characteristics and assumptions of expected conditions and activity levels. This section explains the minimum reporting requirements for CSD and LIWP Providers as contracts are awarded and implemented, termed Phase 1, and after a project is completed, termed Phase 2. Table 2 shows the project phases and when reporting is required.

LIWP Providers have the obligation to provide, or provide access to, data and information on project outcomes to CSD.

It is the responsibility of CSD to collect and compile project data from LIWP Providers, including GHG emission reductions and information on benefits to disadvantaged communities.

Table 2: Quantification and Reporting by Project Phase

	Timeframe	Quantification Methods
Funding Allocation	Upon LIWP Provider contract award, when CSD can estimate the number of projects to be implemented by project type.	CSD uses methods in Section B to **estimate** GHG reductions based on funding allocations.
Phase 1	Upon contract completion, when the LIWP Provider has provided project-specific information (e.g., the number of projects installed by project type, estimated energy savings, installation location).	CSD uses methods in Section C to update GHG reduction **estimates** based on data from LIWP Providers for implemented measures.
Phase 2	Begins after Phase 1 is complete.	GHG reductions **achieved** are quantified and reported for a subset of funded projects.

Phase 1 reporting is required for all LIWP projects. CSD will collect and submit data to ARB to satisfy Phase 1 reporting requirements. LIWP Providers must report any

[33] 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. Accessed on September 12, 2016.

changes that impact GHG emission reduction estimates (i.e., assumptions or quantities) to CSD prior to project completion.

Phase 2 reporting is required for only a subset of LIWP 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. CSD 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 CSD 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 fields needed to support quantification of GHG emission benefits.
- Reporting requirements for transmitting the data to ARB or CSD 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. Emission Factors

Type	Emission Rate	Units
Electricity	0.000303	$MTCO_2e$ per kWh
Natural Gas	0.00531	$MTCO_2e$ per therm
	0.0531	$MTCO_2e$ per mmBtu
Kerosene	0.0755	$MTCO_2e$ per mmBtu
Propane	0.0615	$MTCO_2e$ per mmBtu
Fuel Oil	0.0742	$MTCO_2e$ per mmBtu

Electricity Emission Factor

For the purposes of GGRF quantification methodologies, ARB developed a California grid average electricity emission factor based on total in-state and imported electricity emissions ($MTCO_2e$) divided by total consumption in kWh.

Statewide electricity emissions data were obtained from ARB's GHG Emission Inventory – 2015 Edition. ARB's GHG Emission Inventory compiles facility-specific emissions data from ARB's GHG Mandatory Reporting Program from electricity generation, electricity importers, refineries, cement plants, and other regulated entities. The current 2015 Edition inventory uses global warming potential (GWP) values from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report,[34] consistent with current international and national GHG inventory practices.

The electricity emissions data are derived from the inventory by economic sector located at: https://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_sector_sum_2000-14.pdf (updated March 30, 2016). 2013 emissions data is the most recent data year for the 2015 Edition of the ARB GHG inventory and is the data set used for the FY 2015-16 LIWP Program. The total in-state electricity generation is combined with the total imported electricity and results in 89.84 million tons of CO_2e.

The electricity (in-state generation and imports) data was obtained from CEC's Energy Almanac located at: http://energyalmanac.ca.gov/electricity/electricity_generation.html. The California Code of Regulations (Title 20, Division 2, Chapter 2, Section 1304 (a)(1)-(2)) requires owners of power plants that are 1 megawatt (MW) or larger in California or within a control area with end users inside California to file data on electric generation, fuel use, and environmental attributes. Filings are submitted to the California Energy Commission (CEC) on a quarterly and annual basis. These filings cover all types of electric generation: wind, solar, geothermal, natural gas, hydroelectric, coal generators, and others. Energy Commission staff collect and verify these reports to compile a

[34] Intergovernmental Panel on Climate Change 4th Assessment Report, 2007. Available at: http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm. Accessed on September 12, 2016.

statewide accounting of all electric generation serving California. The total California electricity generation plus net imports for 2013 is 296,203 gigawatt hours (GWh) or equal to 296,203,000,000 kilowatt hours.

The California grid average electricity emission factor is determined by dividing the emissions ($MTCO_2e$) data by the electricity consumption (kWh) data. The 2013 electricity emission factor based on July 27, 2016 data is calculated as follows:

$$\frac{89{,}840{,}000\ MTCO_2e}{296{,}203{,}000{,}000\ kWh} = 0.000303\ \frac{MTCO_2e}{kWh}$$

Heating Fuel Emission Factors

Heating fuels for LIWP projects are natural gas, kerosene, propane, and fuel oil. The heating fuel emission factors are derived from the United States Environmental Protection Agency's (U.S. EPA) Emission Factors for Greenhouse Gas Inventories and is located at: https://www.epa.gov/sites/production/files/2015-12/documents/emission-factors_nov_2015.pdf. The Emission Factors for Greenhouse Gas Inventories uses the global warming potentials (GWP) from the IPCC Fourth Assessment Report.

Gases are converted to $MTCO_2e$ by multiplying by their GWP and converting the units appropriately.

Gas	Units	100-year GWP
CO_2	kg/mmBtu	1
CH_4	g/mmBtu	25
N_2O	g/mmBtu	298

Appendix B. References – Measure Energy Savings

For the energy efficiency component of LIWP, the energy savings values of eligible measures utilize various references to match the LIWP measure with an energy savings value of an equivalent measure. This is necessary because some LIWP measures may not have an equivalent measure in a reference source such as DEER. In these situations, other utility-based energy efficiency program documents are used. The following table lists applicable energy efficiency reference sources.

Reference Source	Website
DEER	http://www.deeresources.com/
Non-DEER measure work papers and CPUC dispositions	http://www.deeresources.com/index.php/non-deer-workpapers
CMUA Energy Efficiency Technical Reference Manual and associated spreadsheets	http://cmua.org/energy-efficiency-technical-resource-manual-2016/
Energy Savings Assistance Program	http://www.calmac.org/ http://eestats.cpuc.ca.gov/
CalTF approved work papers	http://www.caltf.org/approved-measures/

The table below lists LIWP measures for both the Basic LIWP Package and the Enhanced LIWP Package and the applicable references used to obtain a deemed energy savings value for a specific measure. The energy savings values are used to quantify the GHG emission reductions for the corresponding measure by multiplying the appropriate emission factor to the energy savings value.

LIWP Measure	Energy Savings Reference
Hot Water Flow Restrictor, Faucet Restrictor	Water-Energy Grant Program GHG Calculator (latest version for FY 2015-16). Found at: https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/quantification.htm
Hot Water Flow Restrictor, Low Flow Showerhead / Hand-Held Low Flow Showerhead	Water-Energy Grant Program GHG Calculator (latest version for FY 2015-16). Found at: https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/quantification.htm
LED Light Bulbs, Interior / Exterior	CMUA Technical Reference Manual (TRM), June 9, 2016 and associated TRM spreadsheet – TRM204_residential-LED_v3-15-2016.xlsx. Found at:http://cmua.org/energy-efficiency-technical-resource-manual-2016/
LED Night Lights	SCE work paper, SCE13LG029 LED, Electroluminescent plug-in night lights, August 25, 2012. Measure Name: 0.3 Watt Night Light LED replacing Incandescent Night Light. Found at: http://www.deeresources.com/index.php/non-deer-

LIWP Measure	Energy Savings Reference
	workpapers
Vacancy Sensor	PG&E Energy Savings Assistance (ESA) Program Annual Report for Program Year 2013, May 1, 2014. ESAP Table 9. Found at: http://www.liob.org/docs/PGE%202014%20(PY%202013)%20ESA%20&%20CARE%20Annual%20Report.pdf
Tier 2 Advanced Power Strips	Savings Estimation Technical Reference Manual for the California Utilities Association, June 09, 2016; TRM503_Tier-2-APS_v3-15-2016. Found at: http://cmua.org/energy-efficiency-technical-resource-manual-2016/
Thermostatic Shower Valve and Showerhead	Disposition for Water Fixtures, California Public Utilities Commission, Energy Division, February 22, 2013. Found at: http://www.deeresources.com/index.php/non-deer-workpapers
Ceiling Fan	Savings Estimation Technical Reference Manual for the California Utilities Association, June 09, 2016; TRM206_residential-ceiling-fans_v2-18-2014. Found at: http://cmua.org/energy-efficiency-technical-resource-manual-2016/
Ceiling Insulation	"DEER for 2014 Code Update" database, released in November of 2013. RB-BS-CeilIns-R0-R30, RB-BS-CeilIns-R0-R38. Found at: http://www.deeresources.com/ Savings must be quantified by energy audit when there is pre-existing insulation.[35]
Cooling Replacement	Energy savings quantified using energy audit tool.[35]
Duct Repair and Replacement	Energy savings quantified using energy audit tool.[35]
Electronically Commutated Motor (ECM) Blower Motor	Workpaper disposition for Residential HVAC Quality Maintenance CPUC May 2, 2013. Found at: http://www.deeresources.com/index.php/non-deer-workpapers
Efficient Fan Controller	Workpaper PGE3PHVC150 R0 Enhanced Time Delay. Found at: http://www.deeresources.com/index.php/non-deer-workpapers
Floor Insulation	Energy savings quantified using energy audit tool.[35]
Heating Source Replacement	Energy savings quantified using energy audit tool.[35]
Infiltration Reduction	PY2011 Energy Savings Assistance Program Impact

[35] List of approved CEC energy audit software. Available at: http://www.energy.ca.gov/title24/2016standards/2016_computer_prog_list.html
List of approved EUC energy audit tools. Available at: http://homeupgrade.org/2335-2/. Both accessed on September 12, 2016.

LIWP Measure	Energy Savings Reference
	Evaluation Final Report, Study ID:SDG0273.01 August 30, 2013. Found at: http://www.energyefficiencycouncil.org/policy-activity/cpuc/studies Alternative Method: Energy savings quantified using energy audit tool.[35]
Refrigerant Charge w/Coil Cleaning	Savings Estimation Technical Reference Manual for the California Utilities Association, June 09, 2016; TRM224_residential_HVAC-tune-up_refrigeration-charge_V3-15-2016 and TRM226_residential-HVAC-tune-up_coil-cleaning_3-15-2016. Found at: http://cmua.org/energy-efficiency-technical-resource-manual-2016/
Refrigerator Replacement	PG&E Energy Savings Assistance (ESA) Program Annual Report for Program Year 2013, May 1, 2014. ESAP Table 9. Found at: http://www.liob.org/docs/PGE%202014%20(PY%202013)%20ESA%20&%20CARE%20Annual%20Report.pdf
Smart Thermostat	CMUA Technical Reference Manual (TRM), June 9, 2016 and associated TRM spreadsheet – TRM501_web-enabled-programmable-thermostats-residential_3-15-2016.xlsx. Found at: http://cmua.org/energy-efficiency-technical-resource-manual-2016/
Wall Insulation	"DEER for 2014 Code Update" database, released in November of 2013. RB-BS-BlowInIns-R0-R13. Found at: http://www.deeresources.com/
Water Heater Blanket	Evaluation, Measurement, and Verification Report for the Moderate Income Comprehensive Attic Insulation Program #1082-04, Study ID:BOE0001.01. June 12, 2008. Found at: http://www.calmac.org/publications/BO_MICAP_1082_04_EMV_FINAL_Report_BOE000101.pdf
Water Heater Replacement	Energy savings quantified using energy audit tool.[35]
Whole House Fans	CMUA Technical Reference Manual (TRM), June 9, 2016 and associated TRM spreadsheet – TRM202_whole-house-fan_v2-18-2014.xlsx. Found at:http://cmua.org/energy-efficiency-technical-resource-manual-2016/
Window Replacement	Energy savings quantified using energy audit tool.[35]
Solar PV	National Renewable Energy Laboratory PVWatts Calculator. Found at: http://pvwatts.nrel.gov/
Solar Water Heating	CSI Thermal Program Incentive Calculator for Standard-300

LIWP Measure	Energy Savings Reference
	Systems. Found at: https://www.csithermal.com/calculator/