California Air Resources Board

Greenhouse Gas Quantification Methodology for the

Department of Community Services and Development

Low-Income Weatherization Program

Greenhouse Gas Reduction Fund

Fiscal Year 2014-15

December 9, 2015

Table of Contents

A.   Introduction

The California Air Resources Board (ARB) is responsible for providing the quantification methodologies to estimate greenhouse gas (GHG) emission reductions from projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF). ARB staff developed the quantification methodologies outlined in this document to be used by the Department of Community Services and Development (CSD) to estimate GHG emission reductions from Low-Income Weatherization Program (LIWP) projects for Fiscal Year (FY) 2014-15 funds. The weatherization quantification methodologies described in this document pertain only to single-family and small multi-family dwellings. The quantification methods provided estimate emission reductions from the following project types:

- Weatherization
- Solar Water Heaters
- Solar Photovoltaics (PV)

Methodology Development

For the first year (FY 2014-15) of LIWP, ARB and CSD staff followed a set of principles to guide the development of the quantification methodology.

The methodology must:
- Apply at the project-level, for project types being funded by LIWP.
- Provide uniform methods that can be applied statewide.
- Estimate GHG emission reductions from the projected energy savings achievable through weatherization and renewable energy projects installed.
- Use existing and proven tools or methodologies that are supported by empirical literature where available.

The methodologies provide a uniform approach to estimate energy savings, in electricity (kWh) and natural gas (therms), and GHG emission reductions, which are reported in metric tons of carbon dioxide equivalent (MTCO$_2$e), from weatherization and renewable energy projects. A summary of the project types and quantification methodologies are provided in Table 1.

Table 1: Summary of GHG Reduction Projects and Quantification Methodologies

Project Type	Methodologies		Emission Factor	GHG Reductions
Weatherization	Prescriptive	Deemed Savings	Electricity and Natural Gas	MTCO$_2$e
	Performance	Energy Assessment Tools	Electricity and Natural Gas	MTCO$_2$e
Solar Water Heater (SWH)	CSI Solar Thermal Calculator		Electricity or Natural Gas	MTCO$_2$e
Solar Photovoltaics (PV)	PVWatts Calculator		Electricity	MTCO$_2$e

GHG Emission Reductions

This methodology estimates the GHG emission reductions of proposed CSD projects based on the estimated energy savings due to the installation of weatherization, solar water heaters, and solar PV.

CSD will estimate the total GHG emission reductions from the program as a whole over the project life, as defined in the methodology and report results as:

$$\frac{Total\ Project\ GHG\ Emission\ Reduction\ in\ Metric\ Tons\ (MT)\ of\ CO2e\ over\ the\ project\ life}{GGRF\ Funds\ Requested\ (\$)}$$

Program providers will also report the above metric per dwelling and by project type per dwelling. The following sections describe the calculations needed to estimate the GHG emission reductions for proposed projects under the FY 2014-15 CSD LIWP Program.

B.   Quantification Methodology

This methodology estimates the GHG emission reductions of a proposed CSD LIWP projects based on estimated energy savings.

The following is a summary of the methods by project type.

Weatherization

Weatherization includes assessing a dwelling for energy inefficiencies, in order to identify and implement the appropriate upgrades or repairs to improve the overall energy efficiency of the dwelling. A weatherized dwelling in California will reduce GHG emissions by reducing electricity and natural gas consumption. The weatherization quantification methodologies described in this document pertain only to single-family

and small multi-family dwellings. The dwelling types are defined in CSD's LIWP Program Guidelines.[1]

The "Project Case"

The project case represents the estimated GHG emissions expected to occur for a proposed project after the weatherization 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" and the interactive effects of all energy related systems in the dwelling to identify potential sources of inefficiencies. The home energy assessment is designed to generate a list of recommended performance improvement measures that advance the energy efficiency of the dwelling, which subsequently reduces GHG emissions.

LIWP Weatherization services for a particular dwelling will use either a "prescriptive" or a "performance" approach for energy savings measures based on CSD's weatherization assistance program for low-income dwellings funded by the DOE.[2] These approaches will determine the level of home energy assessment rigor and the resulting energy efficiency upgrades selected for a dwelling.

1. **Prescriptive Approach** – Utilizes a specific list of allowable measures based on dwelling type and California Energy Commission (CEC) climate zone[3] that are used for improving the energy efficiency of a home. The anticipated energy savings for the project case utilizes a deemed savings methodology described below.
2. **Performance Approach** – Utilizes a site-specific energy audit to assess energy savings measures based on cost-effectiveness. The anticipated energy savings for the project case utilizes an energy assessment or energy audit tool methodology described below.

Prescriptive Approach: Deemed Savings

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

---

[1] Low-Income Weatherization Program Guidelines. (2015, January 13). Available online at: http://www.csd.ca.gov/LinkClick.aspx?fileticket=XQ-HrGfxnH0%3d&portalid=0
[2] Weatherization Assistance Program for Low-Income Persons. 2014 DOE State Plan. Attachment F. (2014, June 26). Available online at: http://www.csd.ca.gov/Portals/0/Documents/State%20Plans/2013-2014%20DOE%20State%20Plan%206-26-14%20Updated.pdf
[3] CEC – California Climate Zone Maps. Available online at: http://www.energy.ca.gov/maps/renewable/building_climate_zones.html

from historical evaluations.[4] The Database for Energy Efficient Resources (DEER) is a CEC and California Public Utilities Commission (CPUC) sponsored database available at http://www.energy.ca.gov/deer/. 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"[5] estimates of the energy-savings potential for energy-efficient technologies and measures in residential and nonresidential applications.

DEER provides the necessary data elements to apply a deemed savings approach and identify the annual energy savings associated with a 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, heating, ventilation and air conditioning (HVAC), and other measures that can be applied. 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 (use residential single-family and small multi-family dwellings only) for which that measure is applicable. Each measure and its associated energy impact values are then summed to determine a 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 heating, ventilation, and air conditioning (HVAC) interactive effects associated with measure installation, whereas the "direct end-use" energy impact values are the direct energy impacts of the specific measure installed.

When individual weatherization measures are not available in DEER, other industry standard resources may be utilized. These resources are limited to the following:

1. Non-DEER measure work papers and CPUC dispositions submitted by the investor-owned utilities (IOUs) in support of their energy efficiency portfolio applications.[6]
2. California Municipal Utilities Association Energy Efficiency (CMUA) Technical Reference Manual.[7]

---

[4] EPA deemed savings definition available online at:
http://www.epa.gov/statelocalclimate/definitions/deemed-savings.html
[5] Ex ante is Latin for "beforehand." The ex ante process estimates the potential energy savings for an energy efficient measure before it is installed based on predictions of typical operating conditions and baseline usage.
[6] Non-DEER work papers are available online at http://deeresources.com/index.php/non-deer-workpapers/non-deer-work-paper-values-13-14

3. California Technical Forum (CalTF) approved work papers.
4. CSD Priority List analysis methods in accordance with WPN-13-5.[8]

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

$$GHG_{anual\ reductions\ per\ measure} = (DS_{electricity}\ x\ EF_{electricity}\ ) + (DS_{natural\ gas}\ x\ EF_{natural\ gas}) \qquad \text{Eq. 1}$$

$$GHG_{life\ per\ measure} = GHG_{anual\ reductions\ per\ measure}\ x\ EUL_{measure} \qquad \text{Eq. 2}$$

$$GHG_{life} = \sum GHG_{life\ per\ measure}, i \qquad \text{Eq. 3}$$

Where:

- $DS_{electricity}$ = estimated annual deemed savings of electricity for a specific measure (kWh)
- $EF_{electricity}$ = emission factor for electricity (0.000315 $MTCO_2e$ per kWh)[9]
- $DS_{natural\ gas}$ = estimated annual deemed savings of natural gas for a specific measure (therms)
- $EF_{natural\ gas}$ = emission factor for natural gas (0.005311 $MTCO_2e$ per therm)
- $GHG_{annual\ reductions\ per\ measure}$ = annual GHG emission reductions per efficiency measure installed ($MTCO_2e$)
- $EUL_{measure}$ = effective useful life from deemed savings for a specific measure installed as provided by DEER database (years)
- $GHG_{life\ per\ measure}$ = lifetime GHG emission reductions per measure installed ($MTCO_2e$)
- GHG_{life} = total lifetime GHG emissions reduced per dwelling ($MTCO_2e$)
- i = number of measures installed per dwelling (e.g., windows, insulation, etc.)

---

[7] CMUA Technical Reference Manual is available online at http://cmua.org/energy-efficiency-technical-reference-manual
[8] Department of Energy Weatherization Program Notice 13-5 is available online at http://www.waptac.org/data/files/Website_docs/Government/Guidance/2013/WPN-13-5-Revised-Energy-Audit-Procedures-Final.pdf
[9] For the purposes of GGRF quantification methodologies, ARB developed a California grid electricity emission factor based on total in-state and imported electricity emissions ($MTCO_2e$) divided by total consumption in MWh. Emissions from ARB GHG inventory (2012), available online at: http://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_by_sector_00-12_sum_2014-03-24.pdf. Consumption data from CEC Energy Almanac (2012), available online at: http://energyalmanac.ca.gov/electricity/electricity_generation.html

Performance Approach: Energy Assessment Tool

Home energy assessment tools are used as part of the performance approach to determine the energy performance of the dwelling and identify opportunities for energy efficiency improvements. The energy assessment tool utilizes specialized software to determine the dwelling's energy load and estimate energy consumption based on data points collected about the home's geometric characteristics, thermal boundary, location, number of occupants, and energy systems.

There are many home energy assessment tools in the marketplace. These tools may vary considerably in how they collect and analyze a dwelling's characteristics and generate energy efficiency improvement recommendations.[10] The LIWP program will use energy assessment software tools approved by the CEC[11], Energy Upgrade California (EUC)[12], or DOE[13] for compliance with energy efficiency programs.

Quantify estimated GHG emission reductions from calculated energy savings utilizing the energy assessment tools as follows:

$$GHG_{electricity} = EA_{electricity} \; x \; EF_{electricity} \qquad \text{Eq. 4}$$

$$GHG_{natural\;gas} = EA_{natural\;gas} \; x \; EF_{natural\;gas} \qquad \text{Eq. 5}$$

$$GHG_{total} = GHG_{electricity} + \; GHG_{natural\;gas} \qquad \text{Eq. 6}$$

$$GHG_{life} = GHG_{total} \; x \; Life \qquad \text{Eq. 7}$$

Where:

- $EA_{electricity}$ = annual estimated energy assessment savings from electricity of all measures installed (kWh)
- $EF_{electricity}$ = emission factor for electricity (0.000315 $MTCO_2e$ per kWh)
- $GHG_{electricity}$ = annual GHG emissions reduced from electricity ($MTCO_2e$)

---

[10] Review of selected home energy auditing tools, DOE. (2010, November 2). Available online at http://apps1.eere.energy.gov/buildings/publications/pdfs/homescore/auditing_tool_review.pdf
[11] List of approved CEC energy audit software is available online at: http://www.energy.ca.gov/title24/2013standards/2013_computer_prog_list.html
[12] List of approved EUC energy audit tools is available online at: http://www.caltrack.org/caltest.html
[13] List of DOE energy audit tools is available online at: http://www.buildingenergysoftwaretools.com/software-listing?combine=&field_catagory_tid%5B%5D=201&field_platform_tid=All&field_price_tid=All&field_last_updated_value%5Bvalue%5D%5Byear%5D=2010&field_language_tid=All&sort_by=field_rating_rating&items_per_page=60&=Search

- EA $_{natural\ gas}$ = annual estimated energy assessment savings from natural gas of all measures installed (therms)
- EF $_{natural\ gas}$ = emission factor for natural gas (0.005311 $MTCO_2e$ per therm)
- GHG $_{natural\ gas}$ = annual GHG emissions reduced from natural gas ($MTCO_2e$)
- GHG $_{total}$ = sum of annual GHG emissions reduced from electricity and natural gas ($MTCO_2e$)
- Life = estimated average lifetime of measures installed. The average lifetime can be determined utilizing the DEER database EULs for each measure installed (years)
- GHG $_{life}$ = Lifetime GHG emissions reduced per home ($MTCO_2e$)

Solar Water Heater

Solar water heaters (SWH) use radiant heat from the sun to heat either water or a heat-transfer fluid in a roof-mounted collector.[14] SWH systems typically provide 60 percent of the hot water needed by an end-user, with the remainder provided by a back-up water heater powered by natural gas or electricity.[15] 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 emissions expected to occur after SWH installation. The CSI solar thermal calculator[16] 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 upon performance of the SWH system, location, and system design. The CSI solar thermal calculator estimates an energy savings value for SRCC OG-300 rated systems and provides annual system savings estimates for locations in California.

Below are the CSI solar thermal calculator inputs:

- Standard 300 system type
- Site zip code
- Backup water heater type
- Azimuth
- Tilt
- Annual average access – (average annual percentage of access to sun from this solar array from 10:00 am – 3:00 pm PST[17])

---

[14] CPUC Energy Division
[15] CPUC Energy Division – CSI Thermal Program
[16] CSI Thermal Program Incentive Calculator. Available online at https://www.csithermal.com/calculator/
[17] Refer to section 2.3 of the CSI solar thermal handbook for more information.

- 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 annual GHG emission reductions (MTCO$_2$e) and are calculated as follows:

$$GHG_{life} = \sum_{n=1}^{n=x} \left[1 - (n)(R_{degradation})\right](SWH_{savings})(EF) \qquad \text{Eq. 8}$$

Where:

- n = year
- x = length of manufacturer warranty (years)
- $R_{degradation}$ = rate of system degradation (0.5% per year[18])
- $SWH_{savings}$ = annual estimated system savings from CSI solar thermal calculator (kWh or therms)
- EF = emission factor; electricity (0.000315 MTCO$_2$e per kWh), natural gas (0.005311 MTCO$_2$e per therm)
- GHG_{life} = total GHG emissions reduced from SWH system (MTCO$_2$e)

Solar Photovoltaics

Solar PV is 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 grid.

The "Project Case"

The project case represents the estimated GHG emissions expected to occur after solar PV installation. 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 NREL PVWatts calculator[19] is the methodology that will be used to estimate electricity savings from LIWP solar PV installations.

NREL's PVWatts Calculator is a web application developed by the National Renewable Energy Laboratory that estimates the electricity production of a grid-connected roof or ground-mounted photovoltaic system based on a few simple inputs. To use the calculator, information is provided about the system's location, basic design parameters,

---

[18] NRELTechnical Report (2011). "Break-even Cost for Residential Solar Water Heating in the United States: Key Drivers and Sensitivities. Available online at: http://www.nrel.gov/docs/fy11osti/48986.pdf
[19] National Renewable Laboratory PVWatts Calculator. Available online at http://pvwatts.nrel.gov/

and system economics. PVWatts calculates estimated values for the system's annual and monthly electricity production, and for the monetary value of the electricity.

Below are the PVWatts calculator inputs:

- Location
- DC system size (kW)
- Module type
- Array type
- System losses (%)
- Tilt
- Azimuth
- Note: "Loss Calculator" includes the following
  - Soiling (%)
  - Shading (%)
  - Snow (%)
  - Mismatch (%)
  - Wiring (%)
  - Connections (%)
  - Light induced degradation (%)
  - Nameplate rating (%)
  - Age (%)
  - Availability (%)
- NOTE: "Advanced Parameters" includes the following
  - DC to 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 annual GHG emission reductions (MTCO$_2$e) as follows:

$$GHG_{life} = \sum_{n=1}^{n=x} \left[1 - (n)(R_{degradation})\right](PV_{production})(EF_{electricity})$$
Eq. 9

Where:

- n = year
- x = length of manufacturer warranty
- R $_{degradation}$ = rate of system degradation
- PV $_{production}$ = annual estimated kWh generated by solar PV calculator
- EF $_{electricity}$ = emission factor for electricity (0.000315 MTCO$_2$e per kWh)

- GHG $_{life}$ = total GHG emissions (MTCO$_2$e) reduced from solar PV system

C.   Reporting and Documentation

The final step to complete this quantification methodology is to report the Total Project GHG Emission Reductions and provide documentation of the calculations.

Reporting

CSD will report the Total Estimated GHG Emission Reductions from the program as a whole, which is equal to the sum total of each of the Project Type GHG Emission Reductions calculated in Sections B, C, and D, and calculated as follows:

$$Total\ Project\ GHG\ Emission\ Reductions\ in\ MTCO_2e$$
$$= GHG_{life}(from\ weatherization, Section\ B)$$
$$+ GHG_{life}\ (from\ solar\ water\ heaters, Section\ C) \qquad\qquad Eq.\ 10$$
$$+ GHG_{life}\ (from\ solar\ PV, Section\ D)$$

For the CSD LIWP Program, results must be reported as:

$$\frac{Total\ Project\ GHG\ Emission\ Reduction\ in\ Metric\ Tons\ (MT)\ of\ CO2e\ over\ the\ project\ life}{GGRF\ Funds\ Requested\ (\$)}$$

Program providers will also report the above metrics per dwelling and by project type per dwelling.

Documentation

CSD is required to capture and retain documentation that is complete, and sufficient to allow the quantification calculations to be reviewed and replicated.

Documentation will include:

- Contact information for the person who can answer project specific questions from staff reviewers on the quantification calculations;
- Project specific data inputs for weatherization, SWH, and solar PV;
- Quantification methodologies utilized;
- Estimated energy savings per dwelling and by project type per dwelling;
- Project specific equipment specifications and certifications;
- Summary page with, at a minimum, the following information:
    - Total GHG emission reductions from the program as a whole and by project type over the project life
    - GHG emission reductions per dwelling and by project type per dwelling
    - GGRF funds requested

ARB will continue to evaluate and update the GHG emission reduction quantification methodologies as necessary for future FY GGRF appropriations. Quantification methods are posted on ARB's auction proceeds webpage at: http://www.arb.ca.gov/cc/capandtrade/auctionproceeds/quantification.htm
Questions on this document should be forwarded to GGRFProgram@arb.ca.gov