California Air Resources Board

Quantification Methodology

California Conservation Corps
Energy Corps

California Climate Investments

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List of Acronyms and Abbreviations

Acronym	Term
CARB	California Air Resources Board
CCC	California Conservation Corps
CFL	compact fluorescent lamp
DC	direct current
g	grams
GGRF	Greenhouse Gas Reduction Fund
GHG	greenhouse gas
kW	kilowatts
kWh	kilowatt hours
lbs	pounds
LED	light-emitting diode
$MTCO_2e$	metric tons of carbon dioxide equivalent
NO_x	nitrous oxide
$PM_{2.5}$	particulate matter with a diameter less than 2.5 micrometers
PV	photovoltaic
ROG	reactive organic gas
W	watts
yr	year

Section A. Introduction

California Climate Investments is a statewide initiative that puts billions of Cap-and-Trade dollars to work facilitating GHG emission reductions; strengthening the economy; improving public health and the environment; and providing benefits to residents of disadvantaged communities, low-income communities, and low-income households, collectively referred to as "priority populations." Where applicable and to the extent feasible, California Climate Investments must maximize economic, environmental, and public health co-benefits to the State.

CARB is responsible for providing guidance on estimating the GHG emission reductions and co-benefits from projects receiving monies from the GGRF. This guidance includes quantification methodologies, co-benefit assessment methodologies, and benefits calculator tools. CARB develops these methodologies and tools based on the project types eligible for funding by each administering agency, as reflected in the program expenditure records available at: http://www.arb.ca.gov/cci-expenditurerecords.

For the CCC Energy Corps, CARB staff developed this Energy Corps Quantification Methodology to provide guidance for estimating the GHG emission reductions and selected co-benefits from the implementation of solar photovoltaic (PV) installations and building energy efficiency retrofit projects.

The Energy Corps Benefits Calculator Tool automates methods described in this document, provides a link to a step-by-step user guide with a project example, and outlines documentation requirements. Projects will report the total project GHG emission reductions and co-benefits estimated using the Energy Corps Benefits Calculator Tool as well as the total project GHG emission reductions per dollar requested. The Energy Corps Benefits Calculator Tool is available for download at: www.arb.ca.gov/cci-resources.

Using many of the same inputs required to estimate GHG emission reductions, the Energy Corps Benefits Calculator Tool estimates the following co-benefits and key variables from Energy Corps projects:

- Statewide NO_x emission reductions (lbs);
- Statewide ROG emission reductions (lbs);
- Statewide $PM_{2.5}$ emission reductions (lbs);
- Energy and fuel cost savings (dollars);
- Renewable energy generation (kWh); and
- Fossil fuel energy use reductions (kWh).

Additional co-benefits for which CARB assessment methodologies were not incorporated into the Energy Corps Benefits Calculator Tool may also be applicable to the project. Project sponsors should consult the Energy Corps Guidelines[1], solicitation materials, and agreements to ensure they are meeting Energy Corps requirements. All CARB co-benefit assessment methodologies are available at: www.arb.ca.gov/cci-cobenefits.

Methodology Development

CARB and CCC developed this Quantification Methodology consistent with the guiding principles of California Climate Investments, including ensuring transparency and accountability.[2] This Quantification Methodology is used to estimate the outcomes of proposed projects, inform project selection, and track results of funded projects. The implementing principles ensure that the methodology would:

- Apply at the project level;
- Provide uniform methods to be applied statewide and be accessible by all applicants;
- Use existing and proven tools and methods;
- Use project-level data, where available and appropriate; and
- Result in GHG emission reduction estimates that are conservative and supported by empirical literature.

CARB assessed peer-reviewed literature and tools and consulted with experts, as needed, to determine methods appropriate for Energy Corps energy efficiency retrofit and solar PV projects. CARB also consulted with CCC to determine project-level inputs available. The methods were developed to provide estimates that are as accurate as possible with data readily available at the project level.

The Energy Corps Benefits Calculator Tool was developed using data from the California Technical Reference Manual and the California Municipal Utilities Association's Savings Estimation Technical Reference Manual.[3] The California

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[1] California Conservation Corps (2023). Energy Corps. Available at: ccc.ca.gov/what-we-do/conservation-programs/energy-corps/

[2] California Air Resources Board (2018). Funding Guidelines for Agencies that Administer California Climate Investments. Available at: www.arb.ca.gov/cci-fundingguidelines

[3] California Municipal Utilities Association (2017). Savings Estimation Technical Reference Manual [Simplified Nonresidential Lighting Calculator]. Available at: www.cmua.org/energy-efficiency-technical-reference-manual

Municipal Utilities Association compiles the Technical Reference Manual to document the data and methods that publicly owned utilities use to estimate energy savings from their programs. This Quantification Methodology is based on information and equations described in the Simplified Nonresidential Lighting Calculator. The Technical Reference Manual is available at: www.cmua.org/energy-efficiency-technical-reference-manual.

CARB released the Draft Energy Corps Quantification Methodology and Draft Energy Corps Benefits Calculator Tool for public comment in May 2023. This Final Energy Corps Quantification Methodology and accompanying Energy Corps Benefits Calculator Tool have been updated to address public comments, where appropriate, and for consistency with updates to the Energy Corps Guidelines.

In addition, the University of California, Berkeley, in collaboration with CARB, developed assessment methodologies for a variety of co-benefits such as providing cost savings, lessening the impacts and effects of climate change, and strengthening community engagement. Co-benefit assessment methodologies are posted at: www.arb.ca.gov/cci-cobenefits.

Tools

For solar PV projects, the Energy Corps Benefits Calculator Tool relies on project-specific outputs from the National Renewable Energy Laboratory PVWatts® Calculator, a web-based tool that estimates the electricity production of grid-connected roof- or ground-mounted solar PV systems. PVWatts calculates estimated values for the proposed system's monthly and annual electricity production. PVWatts is publicly available to anyone with internet access, free of charge, and is subject to regular updates to incorporate new information. The tool can be accessed at: pvwatts.nrel.gov.

For building energy-efficiency retrofits projects, the Energy Corps Benefits Calculator Tool relies on data from the California Electronic Technical Reference Manual and the California Municipal Utilities Association's Savings Estimation Technical Reference Manual, as mentioned above.[3]

In addition to PVWatts and the Technical Reference Manual, the Energy Corps Benefits Calculator Tool relies on assumptions from CARB-developed emission factors. CARB has established a single repository for emission factors used in CARB benefits calculator tools, referred to as the California Climate Investments Quantification Methodology Emission Factor Database, available at: www.arb.ca.gov/cci-resources. The Emission Factor Database Documentation, also available on the same webpage,

explains how emission factors used in CARB benefits calculator tools are developed and updated.[4]

Project sponsors must estimate the GHG emission reductions and co-benefits of the proposed project with the Energy Corps Benefits Calculator Tool. The Draft Benefits Calculator Tool and Draft Quantification Methodology are subject to change pending stakeholder comments and final Energy Corps Guidelines. The Energy Corps Benefits Calculator Tool can be downloaded from: www.arb.ca.gov/cci-resources.

Updates

CARB 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. CARB updated the Energy Corps Quantification Methodology and Energy Corps Benefits Calculator Tool from the previous versions[5] to enhance the analysis and provide additional clarity, including the following updates:

- Updated grid electricity emission factors for greenhouse gas emissions and air pollution emissions from the most recent California Climate Investments Quantification Methodology Emission Factor Database;[4]
- Added additional building types to the options available in the Energy Corps Benefit Calculator tool for building energy efficiency retrofit projects; and
- Added a quality control step in the Energy Corps Benefit Calculator tool to automatically calculate the number of pre-retrofit and post-retrofit bulbs installed (or number of fixtures and LED kits installed) to help present data entry errors for building energy efficiency retrofit projects.

[4] California Air Resources Board (2023). California Climate Investments Emission Factor Database. Available at: www.arb.ca.gov/cci-resources

[5] For access to previous versions of Quantification Methodologies that are archived from the http://www.arb.ca.gov/cci-resources website, please contact GGRFprogram@arb.ca.gov for access.

Section B. Methods

The following section provides details on the methods supporting emission reductions in the Energy Corps Benefits Calculator Tool.

Project Components

The CCC developed two types of projects that meet the objectives of the Energy Corps and facilitate the reduction of GHG emissions. Other project features may be eligible for funding under the Energy Corps; however, the Energy Corps Quantification Methodology provides methods to estimate GHG emission reductions from projects which install at least one of the following:

- Energy efficient lighting fixtures or controls; or
- Grid-connected solar PV systems.

General Approach

This section describes the methods used in the Energy Corps Benefits Calculator Tool to estimate GHG emission reductions and air pollutant emission co-benefits. These methods account for reductions in electricity use from energy efficiency retrofits and the generation of solar PV electricity.

In general, GHG emission reductions are estimated in the Energy Corps Benefits Calculator Tool based on energy savings from reduced electricity use and avoided grid electricity production. The Energy Corps Benefits Calculator Tool also estimates air pollutant emission co-benefits and key variables using many of the same inputs used to estimate GHG emission reductions.

A. Emission Reductions from Energy Efficiency Retrofits

The following four equations can be used sequentially to estimate total emission reductions from energy efficiency retrofits over the useful life. Equation 1 is used to estimate the annual measure-specific energy use, which can be used to calculate the annual energy use of the pre-retrofit measures and the annual energy use of the post-retrofit measures installed for the project.

Equation 1 should be used for each type of measure installed. For example, the user guide includes a project example for a building energy efficiency retrofit project that replaces 24" fluorescent T12 4-lamps (quantity = 100) with LED 10 Watt bulbs (quantity = 400), and replaces 48" fluorescent T12 4-lamps (quantity = 5) with LED 10 Watt bulbs (quantity = 20). In this scenario, the pre-retrofit annual energy use for the 100 (24") fluorescent T12 4-lamps is calculated using Equation 1. Next, the pre-retrofit annual energy use for the five 48" fluorescent T12 4-lamps would also be calculated using Equation 1 and then both pre-retrofit measures would be summed to estimate the total annual pre-retrofit energy use.

Equation 1. Measure-specific Energy Use

$$Annual\ Energy\ Use_x = \sum_{i=1}^{y} \left(\frac{Watts}{1000} * N * HVAC\ Interactive\ Effect * Operating\ Hours * [1 - CSF] \right)$$

			Units
Energy Use$_x$	=	Annual energy consumption of pre-retrofit or post-retrofit measures	kWh/year
y	=	Number of measures for pre-retrofit baseline scenario or for the post-retrofit installation	unitless
i	=	Each measure for the pre-retrofit baseline scenario or post-retrofit installation. Equation 1 must be completed for each measure-specific lighting fixture and summed across all measures for either the pre-retrofit or post-retrofit lighting fixtures.	unitless
Watts	=	Watts per pre-retrofit or post-retrofit lighting fixture	W
1000	=	Conversion factor from Watts to kilowatts	W/kW
N	=	Measure-specific pre-retrofit or post-retrofit quantity	unitless
HVAC Interactive Effect	=	Building-specific effect factor for interaction between lighting, heating, and/or cooling energy in the climate zone where the project is located	unitless
Operating Hours	=	Building-specific default annual lighting operating hours	hours/year
CSF	=	Control savings factor (CSF) is a control-specific default percent reduction in annual lighting operating hours	%

Equation 2 is used to calculate the annual energy savings based on the difference in energy use between the pre-retrofit measures and post-retrofit measures.

Equation 2. Annual Energy Savings

$$Annual\ Energy\ Savings = Energy\ Use_{Pre-retrofit} - Energy\ Use_{Post-retrofit}$$

			Units
Annual Energy Savings	=	Annual energy use reductions for the project	kWh/year
$Energy\ Use_{Pre-retrofit}$	=	Annual energy consumption of all pre-retrofit measures, summed from Equation 1	kWh/year
$Energy\ Use_{Post-retrofit}$	=	Annual energy consumption of all post-retrofit measures, summed from Equation 1	kWh/year

Based on the annual energy savings calculated in Equation 2, Equation 3 is used to determine total energy savings over the useful life[6] of the project.

Equation 3. Lifetime Energy Savings

$$Total\ Energy\ Savings = Annual\ Energy\ Savings * Useful\ Life$$

Where,			Units
Total Energy Savings	=	Total energy use reductions over the useful life of all post-retrofit measures	kWh
Annual Energy Savings	=	Annual difference in energy use of all post-retrofit measures compared to all pre-retrofit measures, from Equation 2	kWh/year
Useful Life	=	15 years, default estimated useful life of post-retrofit measures[6]	years

[6] The 15-year useful life was obtained from the California Municipal Utilities Savings Estimation Technical Reference Manual. 2017. https://www.cmua.org/energy-efficiency-technical-reference-manual

Finally, Equation 4 is used to calculate the total emission reductions from the project.

Equation 4. Emission Reductions from Energy Efficiency Retrofits

$$Emission\ Reductions = Total\ Energy\ Savings * Emission\ Factor$$

			Units
Emission Reductions	=	Total GHG or criteria and toxic air pollutant emission reductions for the useful life of all post-retrofit measures	$MTCO_2e$ or lbs
Total Energy Savings	=	Total energy use reductions over the useful life of all post-retrofit measures, from Equation 3	kWh
Emission Factor	=	Emission factor for California grid electricity[4]	$MTCO_2e$/kWh or lbs/kWh

B. Emission Reductions from Solar PV Systems

Emission reductions from grid-connected solar PV systems are estimated based on avoided fossil-fuel-based electricity generation, using Equation 5. The annual solar production for the useful life of the solar PV system[7] is adjusted by an estimated annual rate of light-induced degradation[8], and is then multiplied by an emission factor for grid electricity to yield the estimated GHG and air pollution emission reductions.

Please note: Only Solar PV installations that exceed the requirements of Title 24 of the California Code of Regulations may be quantified using the Energy Corps Benefit Calculator Tool.

Equation 5. Emission Reductions from Solar PV Systems

$$Emission\ Reductions = \sum_{n=1}^{30} (1 - R_{degradation})^{n-1} (PV_{production}) (EF_{electricity})$$

Where,			Units
n	=	Any given year	
30	=	Estimated useful life of solar PV systems[7]	years
$R_{degradation}$	=	Rate of system degradation (0.5)[8]	% per year
$PV_{production}$	=	Annual electricity generated based on PVWatts Calculator	kWh per year
$EF_{electricity}$	=	Emission factor for electricity	$MTCO_2e$ per kWh; or lbs per kWh

[7] The 30-year useful life was obtained from the National Renewable Energy Laboratory "Life Cycle Greenhouse Gas Emissions from Solar Photovoltaics" fact sheet. www.nrel.gov/docs/fy13osti/56487.pdf

[8] The estimated rate of system degradation was obtained from the National Renewable Energy Laboratory Technical Report "Photovoltaic Degradation Rates – An Analytical Review." 2012. www.nrel.gov/docs/fy12osti/51664.pdf

Section C. References

The following references were used in the development of this Quantification Methodology and the Energy Corps Benefits Calculator Tool.

California Air Resources Board (2023). *California Climate Investments Quantification Methodology Emission Factor Database*. www.arb.ca.gov/cci-resources

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