California Air Resources Board

Quantification Methodology

California Energy Commission
Food Production Investment Program

California Climate Investments

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List of Acronyms and Abbreviations

Acronym	Term
A	amps
CARB	California Air Resources Board
CEC	California Energy Commission
Diesel PM	diesel particulate matter
DOE	U.S. Department of Energy
FPIP	Food Production Investment Program
GGRF	Greenhouse Gas Reduction Fund
GHG	greenhouse gas
hp	horsepower
kWh	kilowatt hours
lbs	pounds
MEASUR	Manufacturing Energy Assessment Software for Utility Reduction
$MTCO_2e$	metric tons of carbon dioxide equivalent
NOx	nitrous oxide
$PM_{2.5}$	particulate matter with a diameter less than 2.5 micrometers
ROG	reactive organic gas
RMS	root mean square
V	volts

List of Definitions

Term	Definition
Co-benefit	A social, economic, and/or environmental benefit as a result of the proposed project in addition to the GHG emission reduction benefit.
Energy and fuel cost savings	Changes in energy and fuel costs to the operator because of changing the quantity of energy or fuel used conversion to an alternative energy or fuel source, and renewable energy or fuel generation.
Key variable	Project characteristics that contribute to a project’s GHG emission reductions and signal an additional benefit (e.g., renewable energy generated).
Quantification period	Number of years that the project element will provide GHG emission reductions. Sometimes also referred to as "Project Life”.

Section A. Introduction

California Climate Investments is a statewide initiative that puts billions of Cap-and-Trade dollars to work facilitating greenhouse gas (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.

The California Air Resources Board (CARB) is responsible for providing guidance on estimating the GHG emission reductions and co-benefits from projects receiving monies from the Greenhouse Gas Reduction Fund (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: www.arb.ca.gov/cci-expenditurerecords.

For the California Energy Commission (CEC) Food Production Investment Program (FPIP), CARB staff developed this FPIP Quantification Methodology to provide guidance for estimating the GHG emission reductions and selected co-benefits of each proposed project type, as defined in the FPIP guidelines.[1] This methodology uses calculations to estimate GHG emission reductions from replacing equipment with more energy efficient alternatives, installing various efficiency measures, producing renewable energy/fuel, replacing refrigerants with lower global warming potential (GWP) alternatives, and reducing refrigerant leakage rates; and GHG emissions associated with the implementation of FPIP projects.

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

Using many of the same inputs required to estimate GHG emission reductions, the FPIP Benefits Calculator Tool estimates the following co-benefits and key variables from FPIP projects: energy and fuel cost savings ($), fossil fuel-based energy use reductions (kWh and therms), water use reductions (gallons), and renewable energy generation (kWh). Key variables are project characteristics that contribute to a

[1] California Energy Commission. 2019. Food Production Investment Program Guidelines. https://www.energy.ca.gov/research/fpip/documents/

project's GHG emission reductions and signal an additional benefit (e.g., renewable energy generated). Additional co-benefits for which CARB assessment methodologies were not incorporated into the FPIP Benefits Calculator Tool may also be applicable to the project. Applicants should consult the FPIP guidelines, solicitation materials, and agreements to ensure they are meeting FPIP requirements. All CARB co-benefit assessment methodologies are available at: www.arb.ca.gov/cci-cobenefits.

Methodology Development

CARB and CEC developed this Quantification Methodology consistent with the guiding principles of California Climate Investments, including ensuring transparency and accountability.[2] CARB and CEC developed this FPIP Quantification Methodology 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 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 the FPIP project types. CARB also consulted with CEC 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.

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.

[2] California Air Resources Board. www.arb.ca.gov/cci-fundingguidelines

Tools

The FPIP Benefits Calculator Tool may use project-specific outputs from the following tools:

The Manufacturing Energy Assessment Software for Utility Reduction (MEASUR) software tool was developed by the U.S. Department of Energy (DOE) to help manufacturers increase industrial energy efficiency by calculating the efficiency of specific systems and pieces of equipment within a plant. The tool may be used to estimate baseline existing energy consumption and model future project-based energy consumption from pumps, process heating equipment, fans, and steam systems. These outputs can then be inputted into the FPIP Benefits Calculator Tool. The MEASUR tool can be accessed at: https://www.energy.gov/eere/amo/measur.

The AIRMaster+ software tool was developed by the U.S. DOE to help users analyze energy use and savings opportunities in industrial compressed air systems. The tool may be used to estimate baseline existing and model future project-based energy consumption from air compression systems. These outputs can then be inputted into the FPIP Benefits Calculator Tool. The AIRMaster+ tool can be accessed at: https://www.energy.gov/eere/amo/articles/airmaster.

MEASUR and AirMaster+ are used nationally, subject to regular updates to incorporate new information, free of charge, and publicly available to anyone with internet access.

In addition to the tools above, the FPIP Benefits Calculator Tool relies on 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 (Database), available at: http://www.arb.ca.gov/cci-resources. The Database Documentation explains how emission factors used in CARB benefits calculator tools are developed and updated.

Applicants must use the FPIP Benefits Calculator Tool to estimate the GHG emission reductions and co-benefits of the proposed project. The FPIP Benefits Calculator Tool can be downloaded from: http://www.arb.ca.gov/cci-resources.

Section B. Methods

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

Project Type and Components

CEC identified several technologies for projects that meet the objectives of FPIP and for which there are methods to quantify GHG emission reductions.[3] Other project components may be eligible for funding under the FPIP; however, each project requesting GGRF funding must include at least one of the following:

- Installation, replacement, retrofit, or operational optimization to increase energy efficiency of:
    - Compressor controls and system optimization;
    - Machine drive controls and upgrades;
    - Mechanical dewatering;
    - Advanced motors and controls, including variable frequency drives (VFDs);
    - Refrigeration optimization or replacement (including low GWP refrigerants);
    - Drying equipment;
    - Process equipment insulation;
    - Boilers, economizers;
    - Steam traps, condensate return, heat recovery;
    - Evaporators;
    - Internal metering, software, and controls (to manage/control energy usage, with project that reduces energy usage);
    - Other types of controls, such as compressed air, automatic blow down for boilers;
    - Waste heat to power (including pressure reduction turbines);
    - Industrial cooking equipment;
- Renewable electricity generation; and
- Renewable natural gas production.

[3] California Energy Commission. 2019. Food Production Investment Program Guidelines. https://www.energy.ca.gov/research/fpip/documents/

General Approach

Methods used in the FPIP Benefits Calculator Tool for estimating the GHG emission reductions and air pollutant emission co-benefits by project type are provided in this section. The Database Documentation explains how emission factors used in CARB benefits calculator tools are developed and updated.

These methods account for onsite reductions in grid electricity and natural gas usage, additional renewable electricity generation and renewable natural gas production (i.e., beyond that associated with grid electricity reductions), and refrigerant replacement and leakage reduction. In general, the GHG emission reductions are estimated in the FPIP Benefits Calculator Tool using the approaches in Table 1. The FPIP 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.

Table 1. General Approach to Quantification

Food Production Facility Improvement
GHG Emission Reductions = (Baseline energy consumption emissions – Project energy consumption emissions) + (Baseline refrigerant emissions – Project refrigerant emissions) + (Additional GHG benefit of renewable electricity generation) + (Additional GHG benefit of renewable natural gas production)

A. GHG Emission Reductions from Food Production Facility Improvement Projects

Equation 1: GHG Emission Reductions from Food Production Facility Improvement Projects

$$ER_{GHG} = \left(AER_{GHG,Equip} + AER_{GHG,Refrig} + AER_{GHG,Gen}\right) \times Q$$

Where,

			Units
ER_{GHG}	=	Total GHG emission reductions from the project.	$MTCO_2e$
$AER_{GHG,\ Equip}$	=	Annual GHG emission reductions from equipment installation, replacement, retrofit, or optimization (sum of all components, from Equation 2).	$MTCO_2e$/yr
$AER_{GHG,\ Refrig}$	=	Annual GHG emission reductions from refrigerant replacement and leakage reduction (sum of all refrigerants, from Equation 10).	$MTCO_2e$/yr
$AER_{GHG,\ Gen}$	=	Annual GHG emission reductions from the production of renewable energy/fuel (from Equation 11).	$MTCO_2e$/yr
Q	=	Quantification period	Years

Equation 1. The GHG emission reductions from food production facility improvement projects are estimated as the sum of GHG emission reductions from equipment installation, replacement, retrofit, or optimization; refrigerant replacement and leakage reduction; and additional renewable energy/fuel production; multiplied by the quantification period.

Equation 2: Annual GHG Emission Reductions from Equipment Installation, Replacement, Retrofit, or Optimization

$$AER_{GHG,Equip} = \left[\sum\left(NG_{baseline} - NG_{project}\right) \times EF_{GHG,NG}\right] + \left[\sum\left(Elec_{baseline} - Elec_{project}\right) \times EF_{GHG,Elec}\right]$$

Where,

			Units
$AER_{GHG,\ Equip}$	=	Annual GHG emission reductions from equipment installation, replacement, retrofit, or optimization (sum of all components).	$MTCO_2e$/yr
$NG_{baseline}$	=	Baseline annual natural gas consumption for a particular set of components, prior to project implementation (from Equation 3).	therm/yr
$NG_{project}$	=	Future annual natural gas consumption for a particular set of components, after project implementation (from Equation 3).	therm/yr
$EF_{GHG,\ NG}$	=	GHG emission factor for natural gas.	$MTCO_2e$/therm
$Elec_{baseline}$	=	Baseline annual electricity consumption for a particular set of components, prior to project implementation.	kWh/yr
$Elec_{project}$	=	Future annual electricity consumption for a particular set of components, after project implementation.	kWh/yr
$EF_{GHG,\ Elec}$	=	GHG emission factor for grid electricity.	$MTCO_2e$/kWh

Equation 2. Annual GHG emission reductions from equipment installation, replacement, retrofit, and optimization are estimated as the sum of the difference between the baseline and project scenario annual natural gas consumption for all project components, multiplied by the GHG emission factor for natural gas, plus and the sum of the difference between the baseline and project scenario annual electricity consumption for all project components, multiplied by the GHG emission factor for grid electricity.

Equation 3: Annual Natural Gas Consumption

$$NG_x = NG_{comp} \times N$$

Where,

			Units
NG_x	=	Annual natural gas consumption for a particular set of components (x = baseline or project).	therm/yr
NG_{comp}	=	Annual natural gas consumption, per unit or component.	therm/yr/unit
N	=	Number of identical units.	units

Equation 3. Annual natural gas consumption is estimated by multiplying the annual natural gas consumption of each unit or component by the number of identical units.

Equation 4: Annual Electricity Consumption

$$Elec_x = Elec_{comp} \times N$$

Where,

			Units
$Elec_x$	=	Annual electricity consumption for a particular set of components (x = baseline or project).	therm/yr
$Elec_{comp}$	=	Annual electricity consumption, per unit or component.	therm/yr/unit
N	=	Number of identical units.	units

Equation 4. Annual electricity consumption is estimated by multiplying the annual natural gas consumption of each unit or component by the number of identical units.

For the majority of project components, electricity consumption ($Elec_{comp}$) is calculated using a third-party tool or derived from equipment specifications. However, $Elec_{comp}$ for motors and variable speed/frequency drives are calculated within the FPIP Benefits Calculator Tool using Equation 5 and Equation 6, respectively.

Equation 5: Annual Electricity Consumption from Motors

$$Elec_{motor} = AOH_{motor} \times HP_{motor} \times L_{motor} \times 0.746 \times \frac{1}{E_{motor}}$$

Where,			Units
$Elec_{motor}$	=	Annual electricity consumption from a motor.	kWh/yr
AOH_{motor}	=	Annual operating hours for the motor.	hrs/yr
HP_{motor}	=	Motor nameplate horsepower rating.	hp
L_{motor}	=	Motor load.	%
0.746	=	Conversion from hp to kW.	kW/hp
E_{motor}	=	Motor efficiency under actual load conditions.	%

Equation 5. Annual electricity consumption from motors is estimated by multiplying the annual operating hours, nameplate horsepower rating, motor load, and conversion factor (0.746), then dividing by the motor efficiency under actual load conditions.

Equation 6: Annual Electricity Consumption from Variable Frequency Drives

$$Elec_{VFD} = HP_{VFD} \times 0.746 \times \sum_{i}(S_i^3 \times AOH_i)$$

Where,			Units
$Elec_{VFD}$	=	Annual electricity consumption from a variable frequency drive.	kWh/yr
HP_{VFD}	=	Nameplate horsepower rating for the variable frequency drive.	hp
0.746	=	Conversion from hp to kW.	kW/hp
S	=	Operating speed, as a percentage of maximum speed, for each operating condition i.	%
AOH	=	Annual operating hours at a particular speed, for each operating condition i.	hrs/yr

Equation 6. Annual electricity consumption from variable frequency drives is estimated by multiplying the nameplate horsepower rating, conversion factor (0.746), and the summation of operating speed conditions multiplied by the annual operation hours for each respective operating speed.

The FPIP Benefits Calculator Tool also contains calculators that can be used to estimate motors parameters, such as motor load, using Equation 7 – Equation 9.

Equation 7: Motor Load

$$L_{motor} = {}^{P}/_{P_R}$$

Where,			Units
L_{motor}	=	Motor load.	%
P	=	Measured three-phase power.	kW
P_R	=	Input power at full rated load.	kW

Equation 7. Motor load is estimated by dividing the measured three-phase power (Equation 9) by the input power at full rate load (Equation 10).

Equation 8: Motor Input Power at Full Rated Load

$$P_R = \frac{HP_{motor} \times 0.746}{E_R}$$

Where,			Units
P_R	=	Input power at full rated load.	kW
HP_{motor}	=	Motor nameplate horsepower rating.	hp
0.746	=	Conversion from hp to kW.	kW/hp
E_R	=	Motor efficiency at full rated load.	%

Equation 8. Input power at full rated load is estimated by multiplying the horsepower rating by a conversion factor (0.746), then dividing by the motor efficiency at full rated load.

Equation 9: Three-Phase Power

$$P = \frac{V \times I \times PF \times \sqrt{3}}{1{,}000}$$

Where,			Units
P	=	Measured three-phase power.	kW
V	=	RMS voltage, mean line-to-line of three phases.	V
I	=	RMS current, mean of three phases.	A
PF	=	Power factor.	%
$\sqrt{3}$	=	Constant for three phase power.	Unitless
1,000	=	Conversion from kW to W.	W/kW

Equation 9. Measured three-phase power is estimated by multiplying RMS voltage, RMS current, power factor, and a constant for three phase power (√3), then dividing by a conversion factor (1,000).

Equation 10: Annual GHG Emission Reductions from Refrigerant Replacement and Leakage Reduction

$$AER_{GHG,Refrig} = \sum_{i=1}^{n}\left(RC_{baseline} \times GWP_{baseline} \times LR_{baseline} \times N_i/2{,}205\right) - \sum_{j=1}^{m}\left(RC_{project} \times GWP_{project} \times LR_{project} \times N_j/2{,}205\right)$$

Where,			Units
$AER_{GHG,\,Refrig}$	=	Annual GHG emission reductions from refrigerant replacement and leakage reduction (sum of all refrigerants).	$MTCO_2e/yr$
$RC_{baseline}$	=	Refrigerant charge of the baseline refrigeration system.	lb
$GWP_{baseline}$	=	Global Warming Potential of the baseline refrigerant	$MTCO_2e/MT$
$LR_{baseline}$	=	Refrigerant leakage rate of the baseline refrigeration system.	%/yr
$RC_{project}$	=	Refrigerant charge of the refrigeration system proposed by the project.	lb
$GWP_{project}$	=	Global Warming Potential of the refrigerant proposed by the project.	$MTCO_2e/MT$
$LR_{project}$	=	Refrigerant leakage rate of the refrigeration system proposed by the project.	%/yr
N	=	Number of identical units.	units
2,205	=	Conversion factor from pounds to metric tons	lb/MT

Equation 10. Annual GHG emission reductions from refrigerant replacement and leakage reduction are estimated as the difference between the baseline and project scenarios. The baseline and project scenarios are estimated as the multiplication of the refrigerant charge, global warming potential, refrigerant leakage rate, and number of identical units, divided by a conversion factor (2,205).

Equation 11: Annual GHG Emission Reductions from Additional Renewable Energy/Fuel Production

$$AER_{GHG,Gen} = \left(RenElec \times EF_{GHG,Elec}\right) + \left(RNG \times EF_{GHG,NG}\right)$$

Where,			Units
$AER_{GHG,\,Gen}$	=	Annual GHG emission reductions from the production of renewable energy/fuel.	$MTCO_2e/yr$
RenElec	=	Annual renewable electricity generation as a result of the project.	kWh/yr
$EF_{GHG,\,Elec}$	=	GHG emission factor for grid electricity.	$MTCO_2e/kWh$
RNG	=	Annual renewable natural gas production as a result of the project.	kWh/therm
$EF_{GHG,\,NG}$	=	GHG emission factor for natural gas.	$MTCO_2e/therm$

Equation 11. Annual GHG emission reductions from additional renewable energy/fuel production are estimated as the sum of annual renewable electricity generation multiplied by the GHG emission factor for grid electricity, plus annual renewable natural gas production multiplied by the GHG emission factor for natural gas.

B. Air Pollutant Reductions from Food Production Facility Improvement Projects

Equation 12: Air Pollutant Emission Reductions from Food Production Facility Improvement Projects

$$ER_{AP} = ER_{AP,Local} + ER_{AP,Remote}$$

Where,			Units
ER_{AP}	=	Total air pollutant emission reductions from the project.	lb
$ER_{AP,\ Local}$	=	Total onsite air pollutant emission reductions from food production facility improvement projects.	lb
$ER_{AP,\ Remote}$	=	Total offsite air pollutant emission reductions from food production facility improvement projects.	lb

Equation 12. The criteria and toxic air pollutant emission reductions ($PM_{2.5}$, NO_x, and ROG) from food production facility improvement projects are estimated as the sum of local (Equation 13 and Equation 14) and remote (Equation 15, Equation 16, and Equation 17) air pollutant emission reductions.

Equation 13: Local Air Pollutant Emission Reductions from Food Production Facility Improvement Projects

$$ER_{AP,Local} = AER_{AP,NG} \times Q$$

Where,			Units
$ER_{AP,\ Local}$	=	Total onsite air pollutant emission reductions from food production facility improvement projects.	lb
$AER_{AP,\ NG}$	=	Annual avoided air pollutant emissions from the reduced onsite use of natural gas.	lb/yr
Q	=	Quantification period	Years

Equation 13. Local air pollutant emission reductions are estimated by multiplying the annual avoided air pollutant emissions from reduced onsite use of natural gas by the quantification period.

Equation 14: Annual Air Pollutant Emission Reductions from the Reduced Onsite Use of Natural Gas

$$AER_{AP,NG} = \sum (NG_{baseline} - NG_{project}) \times EF_{AP,NG}$$

Where,			Units
$AER_{AP,NG}$	=	Annual avoided air pollutant emissions from the reduced onsite use of natural gas.	lb/yr
$NG_{baseline}$	=	Baseline annual natural gas consumption for a particular set of components, prior to project implementation.	therm/yr
$NG_{project}$	=	Future annual natural gas consumption for a particular set of components, after project implementation.	therm/yr
$EF_{AP,NG}$	=	Air pollutant emission factor for natural gas.	lb/therm

Equation 14. The annual air pollutant emission reductions from the reduced onsite use of natural gas is estimated as the sum of the difference between the baseline and project scenario annual natural gas consumption for all project components, multiplied by the air pollutant emission factor for natural gas.

Equation 15: Remote Air Pollutant Emission Reductions from Food Production Facility Improvement Projects

$$ER_{AP,Remote} = (AER_{AP,Elec} + AER_{AP,RenElec}) \times Q$$

Where,			Units
$ER_{AP,Remote}$	=	Total offsite air pollutant emission reductions from food production facility improvement projects.	lb
$AER_{AP,Elec}$	=	Annual avoided air pollutant emissions from the reduced onsite use of grid electricity.	lb/yr
$AER_{AP,RenElec}$	=	Annual avoided emissions from the generation of renewable electricity.	lb/yr
Q	=	Quantification period	Years

Equation 15. Remote air pollutant emission reductions are estimated by the sum of annual avoided air pollutant emissions from reduced onsite use of grid electricity and from production of renewable electricity, multiplied by the quantification period.

Equation 16: Annual Air Pollutant Emission Reductions from the Reduced Onsite Use of Grid Electricity

$$AER_{AP,Elec} = \sum (Elec_{baseline} - Elec_{project}) \times EF_{AP,Elec}$$

Where,			Units
$AER_{AP,\ Elec}$	=	Annual avoided air pollutant emissions from the reduced onsite use of grid electricity.	lb/yr
$Elec_{baseline}$	=	Baseline annual electricity consumption for a particular set of components, prior to project implementation.	kWh/yr
$Elec_{project}$	=	Future annual electricity consumption for a particular set of components, after project implementation.	kWh/yr
$EF_{AP,\ Elec}$	=	Air pollutant emission factor for grid electricity.	lb/kWh

Equation 16. The annual air pollutant emission reductions from the reduced onsite use of grid electricity is estimated as the sum of the difference between the baseline and project scenario annual electricity consumption for all project components, multiplied by the air pollutant emission factor for grid electricity.

Equation 17: Annual Air Pollutant Emission Reductions from the Generation of Additional Renewable Electricity

$$AER_{AP,RenElec} = RenElec \times EF_{AP,Elec}$$

Where,			Units
$AER_{AP,\ RenElec}$	=	Annual avoided emissions from the generation of renewable electricity.	lb/yr
$RenElec$	=	Annual renewable electricity generation as a result of the project.	kWh/yr
$EF_{AP,\ Elec}$	=	Air pollutant emission factor for grid electricity.	lb/kWh

Equation 17. The annual air pollutant emission reductions from the generation of renewable electricity is estimated as the annual renewable electricity generation multiplied by the air pollutant emission factor for grid electricity.

Section C. References

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

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