California Air Resources Board

Quantification Methodology

California Energy Commission
Industrial Decarbonization and Improvement of Grid Operations Program

California Climate Investments

Note:

The California Air Resources Board (CARB) is accepting public comments on the Draft Industrial Decarbonization and Improvement of Grid Operations (INDIGO) Program Quantification Methodology until April 16th via the *GGRF program email*. The Draft Quantification Methodology is subject to change pending stakeholder comments. The Final INDIGO Quantification Methodology will be available on the *California Climate Investments resources webpage*.

DRAFT
April 2, 2024

Table of Contents

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
GGRF	Greenhouse Gas Reduction Fund
GHG	greenhouse gas
hp	horsepower
INDIGO	Industrial Decarbonization and Improvement of Grid Operations
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.”

DRAFT

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 on the *California Climate Investments Attestation Memorandums and Expenditure Records webpage*.

For the California Energy Commission (CEC) Industrial Decarbonization and Improvement of Grid Operations (INDIGO) Program, CARB staff developed this INDIGO Quantification Methodology to provide guidance for estimating the GHG emission reductions and selected co-benefits of each proposed project type, as defined in the *INDIGO Program solicitation materials*. This methodology uses calculations to estimate GHG emission reductions from replacing equipment with more energy efficient alternatives, installing various efficiency measures, producing renewable energy, among other project types; and GHG emissions associated with the implementation of INDIGO projects.

The INDIGO 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 INDIGO Benefits Calculator Tool as well as the total project GHG emission reductions per dollar of GGRF funds requested. The INDIGO Benefits Calculator Tool is available for download on the *California Climate Investments resources webpage*.

Using many of the same inputs required to estimate GHG emission reductions, the INDIGO Benefits Calculator Tool estimates the following co-benefits and key variables from INDIGO 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 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 INDIGO Benefits Calculator Tool may also be applicable to the project. Applicants should consult the INDIGO Program guidelines, solicitation materials, and/or agreements to ensure they are meeting INDIGO Program requirements. All CARB co-benefit assessment methodologies are available on the *California Climate Investments Co-benefit Assessment Methodologies webpage*.

Methodology Development

CARB and CEC developed this Quantification Methodology consistent with the guiding principles of *California Climate Investments Funding Guidelines for Administering Agencies*, including ensuring transparency and accountability. CARB and CEC developed this INDIGO 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 INDIGO 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 on the *California Climate Investments Co-benefit Assessment Methodologies webpage*.

Tools

The INDIGO 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 INDIGO Benefits Calculator Tool.

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 INDIGO Benefits Calculator Tool.

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 INDIGO 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). The Database Documentation explains how emission factors used in CARB benefits calculator tools are developed and updated.

Applicants must use the INDIGO Benefits Calculator Tool to estimate the GHG emission reductions and co-benefits of the proposed project. The INDIGO Benefits Calculator Tool can be downloaded from the *California Climate Investments resources webpage*.

Program Assistance

Applicants should use the following resources for additional questions and comments:

- Questions on this document should be sent to the *GGRF program email*.
- For more information on CARB's efforts to support implementation of California Climate Investments, see the *California Climate Investments webpage*.
- Questions pertaining to the INDIGO Program should be sent to *Paty De La Torre*.

Section B. Methods

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

Project Type and Components

CEC identified several technologies for projects that meet the objectives of the INDIGO Program and for which there are methods to quantify GHG emission reductions. Other project components are not quantified but may still be eligible for funding under the INDIGO Program (e.g., load flexibility projects). Eligible technologies for funding include, but are not limited to:

- Process Heat Electrification, such as:
  - Industrial heat pumps;
  - Electric boilers/kilns;
  - Infrared heating;
  - Microwave heating;
  - Inductive heating;
- Non-Thermal Separation, such as:
  - Membranes;
  - Freeze distillation;
- Alternative Processes, such as:
  - Alternative materials and feedstocks;
  - Electrolysis;
- Energy Efficiency, such as:
  - Process integration and intensification;
  - Advanced catalysts;
  - Sensors and controls for electrical optimization; and
  - Advanced motors and controls.

General Approach

Methods used in the INDIGO 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, and additional renewable electricity generation (i.e., beyond that associated with grid electricity reductions). In general, the GHG emission reductions are estimated in the INDIGO Benefits Calculator Tool using the approaches in Equation 1. The INDIGO 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.

Equation 1. General Approach to Quantification

GHG Emission Reductions = (Baseline energy consumption emissions – Project energy consumption emissions) + (Additional GHG benefit of renewable electricity generation)

Table 1. Variable Definitions for Equation 1

Variable	Variable Definition	Units
GHG Emission Reductions	Total emissions reductions for the proposed project.	$MTCO_2e$
Baseline energy consumption emissions	Emissions associated with the baseline equipment.	$MTCO_2e$
Project energy consumption emissions	Emissions associated with the equipment proposed for the project.	$MTCO_2e$
Additional GHG benefit of renewable electricity generation	Additional emission reductions associated with renewable electricity generation proposed for the project.	$MTCO_2e$

A. GHG Emission Reductions from Facility Improvement Projects

Equation 2. GHG Emission Reductions from Facility Improvement Projects

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

Table 2. Variable Definitions for Equation 2

Variable	Variable Definition	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 3).	$MTCO_2e$/ year
$AER_{GHG, Gen}$	Annual GHG emission reductions from the production of renewable energy (from Equation 11).	$MTCO_2e$/ year
Q	Quantification period.	Years

Equation 3. Annual GHG Emission Reductions from Equipment Installation, Replacement, Retrofit, or Optimization

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

Table 3. Variable Definitions for Equation 3

Variable	Variable Definition	Units
$AER_{GHG, Equip}$	Annual GHG emission reductions from equipment installation, replacement, retrofit, or optimization (sum of all components).	$MTCO_2e$/year
$NG_{baseline}$	Baseline annual natural gas consumption for a particular set of components, prior to project implementation (from Equation 4).	therm/year
$NG_{project}$	Future annual natural gas consumption for a particular set of components, after project implementation (from Equation 4).	therm/year
$EF_{GHG, NG}$	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 (from Equation 5).	kWh/year
$Elec_{project}$	Future annual electricity consumption for a particular set of components, after project implementation (from Equation 5).	kWh/year
$EF_{GHG, Elec}$	GHG emission factor for grid electricity.	$MTCO_2e$/kWh

Equation 4. Annual Natural Gas Consumption

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

Table 4. Variable Definitions for Equation 4

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

Equation 5. Annual Electricity Consumption

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

Table 5. Variable Definitions for Equation 5

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

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 INDIGO Benefits Calculator Tool using Equations 6 and 7, respectively.

Equation 6. Annual Electricity Consumption from Motors

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

Table 6. Variable Definitions for Equation 6

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

Equation 7. Annual Electricity Consumption from Variable Frequency Drives

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

Table 7. Variable Definitions for Equation 7

Variable	Variable Definition	Units
$Elec_{VFD}$	Annual electricity consumption from a variable frequency drive.	kWh/year
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.	hours/year

The INDIGO Benefits Calculator Tool also contains calculators that can be used to estimate motors parameters, such as motor load, using Equations 8 through 10.

Equation 8. Motor Load Factor

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

Table 8. Variable Definitions for Equation 8

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

Equation 9. Motor Input Power at Full Rated Load

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

Table 9. Variable Definitions for Equation 9

Variable	Variable Definition	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 10. Three-Phase Power

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

Table 10. Variable Definitions for Equation 10

Variable	Variable Definition	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.	N/A
1,000	Conversion from kW to W.	W/kW

Annual GHG emission reductions from additional renewable energy production are calculated as the avoided emissions from grid electricity using Equation 11.

Equation 11. Annual GHG Emission Reductions from Additional Renewable Energy Production

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

Table 11. Variable Definitions for Equation 11

Variable	Variable Definition	Units
$AER_{GHG,\ Gen}$	Annual GHG emission reductions from the production of renewable energy/fuel.	$MTCO_2e$/year
RenElec	Annual renewable electricity generation as a result of the project.	kWh/year
$EF_{GHG,\ Elec}$	GHG emission factor for grid electricity.	$MTCO_2e$/kWh

B. Air Pollutant Reductions from Facility Improvement Projects

The criteria and toxic air pollutant emission reductions ($PM_{2.5}$, NO_x, and ROG) from facility improvement projects are estimated as the sum of local and remote air pollutant emission reductions using Equation 12. Note: the INDIGO Benefits Calculator Tool outputs total local emissions only for determining project-related benefits estimates and reporting purposes.

Equation 12. Air Pollutant Emission Reductions from Facility Improvement Projects

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

Table 12. Variable Definitions for Equation 12

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

Local air pollutant emission reductions are calculated by accounting for the reduced onsite use of natural gas using Equation 13. The annual air pollutant emission reductions from the reduced onsite use of natural gas is calculated as the difference between the baseline and project scenarios using Equation 14.

Equation 13. Local Air Pollutant Emission Reductions from Facility Improvement Projects

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

Table 13. Variable Definitions for Equation 13

Variable	Variable Definition	Units
$ER_{AP, Local}$	Total onsite air pollutant emission reductions from facility improvement projects.	lb
$AER_{AP, NG}$	Annual avoided air pollutant emissions from the reduced onsite use of natural gas.	lb/year
Q	Quantification period.	years

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

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

Table 14. Variable Definitions for Equation 14

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

Remote air pollutant emission reductions are calculated by accounting for the reduced onsite use of grid electricity and the production of renewable electricity using Equation 15. The annual air pollutant emission reductions from the reduced onsite use of grid electricity is calculated as the difference between the baseline and project scenarios using Equation 16. The annual air pollutant emission reductions from the generation of renewable electricity is likewise calculated as the difference between the baseline and project scenarios using Equation 17.

Equation 15. Remote Air Pollutant Emission Reductions from Facility Improvement Projects

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

Table 15. Variable Definitions for Equation 15

Variable	Variable Definition	Units
$ER_{AP,\ Remote}$	Total offsite air pollutant emission reductions from facility improvement projects.	lb
$AER_{AP,\ Elec}$	Annual avoided air pollutant emissions from the reduced onsite use of grid electricity.	lb/year
$AER_{AP,\ RenElec}$	Annual avoided emissions from the generation of renewable electricity.	lb/year
Q	Quantification period.	years

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

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

Table 16. Variable Definitions for Equation 16

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

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

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

Table 17. Variable Definitions for Equation 17

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

Section C. References

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

California Air Resources Board. (2009). Definitions of VOC and ROG. Retrieved from: *https://www.arb.ca.gov/ei/speciate/voc_rog_dfn_1_09.pdf*.

California Air Resources Board. (2022). California Greenhouse Gas Inventory for 2000-2020. Retrieved from: *https://ww2.arb.ca.gov/ghg-inventory-data*.

California Energy Commission. (2023). California Electrical Energy Generation. Retrieved from: *https://www.energy.ca.gov/almanac/electricity_data/electricity_generation.html*.

United State Department of Energy. (2014). Premium Efficiency Motor Selection and Application Guide: A Handbook for Industry. Retrieved from: *https://www.energy.gov/sites/prod/files/2014/04/f15/amo_motors_handbook_web.pdf*.

United States Environmental Protection Agency. (2000). Compilation of Air Pollutant Emission Factors (AP-42), Fifth Edition, Volume 1, Stationary Point and Area Sources. Retrieved from: *https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors*.

United States Environmental Protection Agency. (2018). EPA Emission Factors for Greenhouse Gas Inventories. Retrieved from: *https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf*.