Appendix A: Emission Reduction Quantification

Table of Contents

Section A-1: Overview

In the Budget Act 0f 2024, the California Air Resources Board (CARB) was appropriated $34.94 million from the Air Quality Improvement Fund (AQIF) for incentive projects described in this Proposed Fiscal Year (FY) 2024-25 Funding Plan for Clean Transportation Incentives (Proposed Funding Plan). The proposed project allocations are $14.97 million to Clean Off-Road Equipment (CORE), $14.97 million to Innovative Small e-Fleets (ISEF), and $5 million to Zero-Emission Truck Loan Pilot (ZE-TLP). This Appendix provides projected emission reductions, benefit-cost scores, and other metrics for the proposed project allocations in the Proposed Funding Plan. The methods and assumptions used for the quantification of project metrics are described herein. Assembly Bill (AB) 8 (Perea, Chapter 401, Statutes of 2013) and published GGRF quantification methodologies guided this analysis. It is important to note that projections are illustrative examples of what might be achieved with the allocated funding to projects. In addition, this year, no new funding was received from the Greenhouse Gas Reduction Fund (GGRF), so the scope of this Appendix and potential emission reductions differ substantially from previous years. Refined emission reduction estimates will be quantified as projects are implemented and data becomes available.

Projections of project metrics use three CARB models: CARB's California-specific version of Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model[i] (known as the CA-GREET 3.0 model), CARB's EMission FACtors (EMFAC2021) model[ii], and CARB's Job Co-benefit Assessment Methodology and Modeling Tool[iii]. Publicly available technical reports, incentive-program data, and estimations are also used when projecting project metrics. The types of emissions considered in this Appendix A are greenhouse gases (GHG) calculated in terms of their carbon-dioxide equivalency (CO_2e), oxides of nitrogen (NO_X), particulate matter of less than 2.5 microns in size (PM2.5), and reactive organic gases (ROG). California considers NO_X, PM2.5, and ROG as criteria pollutants. The categories of California jobs supported by the projects in this Proposed Funding Plan are direct, indirect, and induced jobs.

The CORE, ISEF, and ZE-TLP projects are summarized in Table A-1 with their allocations of AQIP funding dollars, projected project-lifetime tonnes of GHG emission reductions, projected project-lifetime tonnes of criteria-pollutant emission reductions, and projected number (N) of vehicles or pieces of equipment provided funding.

---

[i] https://ww2.arb.ca.gov/resources/documents/lcfs-life-cycle-analysis-models-and-documentation
[ii] https://arb.ca.gov/emfac/
[iii] https://www.arb.ca.gov/resources/documents/cci-methodologies

Table A-1: Project, Funding Dollars, Metric Tons of GHG Emission Reductions, Tons of Criteria Pollutant Emission Reductions, and Number of Vehicles/Equipment

Project	Allocation	GHG	NO_X	PM2.5	ROG	$\mathcal{N}$
CORE	$14,970,000	4,618	17.54	0.18	4.71	112
ISEF	$14,970,000	2,881	1.59	0.06	0.10	71
ZE-TLP	$5,000,000	33,232	14.60	0.48	0.54	787

Section A-2: Emission Factors

Emission factors ($\mathcal{F}$) are quantities of emissions per distance traveled or emissions per time for various pieces of on-road or off-road equipment, respectively, in categories provided by EMFAC2021. Energy type, truck class, model year (MY), and engine power were used to further specify emission factors in these categories. Emission factors are used to quantify all project emission metrics.

Emission factors for NO_X, PM2.5, and ROG are calculated based solely on equipment emissions because of their localized impact. Emissions of PM2.5 include those from on-road brake and tire wear, in addition to tailpipe exhaust. All emission factors used herein were determined from the EMFAC2021 database. Documentation of how EMFAC2021 models emissions is publicly available on the CARB website.[iv] The database of all EMFAC2021 modeled quantities is also publicly available on the CARB website.

GHG emission factors are developed on a well-to-wheel (WTW) basis because GHG emissions are global pollutants, where their effects are not proximate to when and where they are created. This WTW basis means that the GHG emissions generated by providing the utilized energy are included in the total GHG emissions projected. This WTW basis is accomplished here by using carbon-equivalent intensities (i) from the CA-GREET 3.0 model in addition to the EMFAC2021 database. The grams of CO_2e per megajoule carbon-equivalent intensities used in our calculations are 100.45 for diesel and 80.55 for electricity.

For on-road vehicles, these carbon-equivalent intensities are multiplied by the energy densities (p) of their respective energy types to produce the carbon-equivalent densities for the various types of energy considered. The energy density of 134.47 megajoules per gallon for diesel used in this Appendix A comes from the CA-

[iv] https://ww2.arb.ca.gov/our-work/programs/msei/emfac2021-model-and-documentation

GREET 3.0 model. The GHG emission factors ($\mathcal{F}_{GHG}$) for on-road equipment are the ratio of the carbon-equivalent densities ($p \cdot i$) to the use efficiencies (ω) of the equipment that utilize the energy. The use efficiencies are pulled from the EMFAC2021 database as the ratio of miles traveled to energy consumed. The overall calculation used here for the GHG emission factors for on-road equipment is shown in Equation A-1 in terms of quantities defined here.

Equation A-1: GHG Emission Factors

$$\mathcal{F}_{GHG} = \frac{p \cdot i}{\omega}$$

For off-road equipment, a different approach is used for GHG emission factors because their use efficiencies cannot be derived from the EMFAC2021 database. The carbon-dioxide (CO_2) emission factors from EMFAC2021 are converted into CO_2-equivalent emission factors for off-road equipment. This conversion is done by multiplying the CO_2 emission factors ($\mathcal{F}_{CO2}$) by the ratio of carbon-equivalent intensity (i_{GHG}) to carbon intensity (i_{CO2}) for diesel. Equation A-2 shows this conversion in terms of quantities defined here. For battery-electric (BE) off-road equipment, the same usage as their replaced internal-combustion engine (ICE) is assumed along with an energy-efficiency ratio (h). Equation A-3 specifies the calculation of GHG emission factors for battery-electric equipment in terms of the quantities defined here.

Equation A-2: Off-Road GHG Emission Factors

$$\mathcal{F}_{\mathrm{GHG}} = \mathcal{F}_{\mathrm{CO2}} \cdot \left(\frac{i_{GHG}}{i_{CO2}}\right)$$

Equation A-3: Off-Road Battery-Electric GHG Emission Factors

$$\mathcal{F}_{\mathrm{GHG,BE}} = \mathcal{F}_{\mathrm{CO2,ICE}} \cdot \left(\frac{i_{GHG,BE}}{i_{CO2,ICE}}\right) \cdot h$$

Section A-3: Project Metrics

To facilitate the comparison of all incentive projects described in this Proposed Funding Plan, the same metrics are consistently applied to each. These metrics are all projections of what these projects might achieve and are all reported here. The topline metrics calculated for this Appendix A are:

- the number of vehicles or pieces of equipment provided funding,
- the average annual emission reductions per piece of equipment in operation,
- the total emission reductions over the lifetime of the project,

- the benefit-cost scores for each project, and
- and the California jobs supported by each project.

The total number of equipment put into operation for a project (N) is estimated from previous and/or expected project performance. The ratio of total project funds (D) and average per equipment project cost (c) yields the estimated number of project funded equipment. This calculation is shown in Equation A-4.

Equation A-4: Number of Equipment Provided Project Funding

$$N = D/c$$

Emission factors are used to estimate emission reductions created by each project specified in this Appendix A. The average annual usage (u) of project funded equipment are combined, when necessary, with their relevant baseline and replacement emission factors to estimate the average annual emission reductions per equipment (r). This calculation is shown in Equation A-5 in terms of quantities defined here.

Equation A-5: Average Annual Emission Reductions per Equipment

$$r = \left(\mathcal{F}_{\mathbf{baseline}} - \mathcal{F}_{\mathbf{replacement}}\right) \cdot u$$

Total project emission reductions (R) are tabulated by multiplying projected annual per-equipment reductions with the total number of funded equipment and the number of equipment ownership years to meet project requirements (Y). This tabulation is shown in Equation A-6 in terms of quantities defined here.

Equation A-6: Project Emission Reductions

$$R = r \cdot N \cdot Y$$

Benefit-cost scores ($\mathcal{B}$) are calculated as the ratio of total project emission reductions (the benefit) to total CARB funding allocated to that project (the cost). This calculation of benefit-cost score is consistent with the AB 8 definition for purposes of the Air Quality Improvement Program. This Appendix A has expanded its use beyond criteria pollutants to include GHG and has applied it to all projects with new funding in this Funding Plan. Equation A-7 shows the calculation of benefit-cost scores.

Equation A-7: Benefit-Cost Score

$$\mathcal{B} = R/D$$

Direct, indirect, and induced jobs are defined as one full-time equivalent employee position in California over one year, equal to approximately 2,080 hours of work. Directly supported jobs refers to labor to complete projects, make equipment, and produce materials, through direct employment or contracted work, paid for with program funds. Indirectly supported jobs exist in the supply chains supporting projects. Funding a project generates demand for intermediate inputs of materials and equipment needed to complete the project, leading to expanded production and employment in the relevant upstream industries. Induced jobs are linked to the spending of income from directly and indirectly supported jobs. The personal consumption expenditures of workers in jobs directly and indirectly supported by Low Carbon Transportation investment projects stimulate demand for goods and services in the wider California economy.

A detailed documentation of the methodology for assessing the number of jobs supported and the comprehensive steps that went into its development can be found on CARB's California Climate Investments Co-Benefit Assessment Methodologies page.[v] Based on inputs such as proposed funding and its percentage going to the actual vehicle or equipment procurement, the number of jobs supported for each of the Low Carbon Transportation project categories was determined using this jobs assessment methodology. The numbers of determined jobs are listed in Table A-10.

Section A-4: Projects with New Funding

Of the $34.94 million total from AQIP, this Funding Plan allocates $14.97 million to CORE, $14.97 million to ISEF, and $5 million to ZE-TLP.

Clean Off-Road Equipment

CORE achieves emission reductions by accelerating the deployment of zero-emission off-road technologies by reducing the up-front costs of such equipment. Eligible equipment types include agricultural equipment, airport ground support equipment, cargo handling equipment, commercial harbor craft, construction equipment, heavier lift forklifts, mobile power units, railcar movers and freight locomotives, and transport refrigeration units. Non-tailpipe emissions of PM2.5 are not accounted for in this analysis of CORE. Because CORE can fund a variety of equipment categories, it is important to note that the analysis in this Appendix A is an illustrative example of the potential emission reductions that may be achieved through this project funding.

In recent CORE voucher request data, the majority of project funding went to six equipment categories. These categories are Agricultural Tractors, Heavier Lift Forklifts, Container Handlers, Construction Loaders, Mobile Power Units, and Transport Refrigeration Units. These six categories are used here in this Appendix A to project future CORE emission reductions and are further described in Table A-2.

---

[v] *https://www.arb.ca.gov/resources/documents/cci-methodologies*

Table A-2: CORE Projection Equipment Categories

Category	Fund Allocation	Horsepower	Voucher
Agricultural Tractors	21%	50 – 75	$80,200
Heavier Lift Forklifts	13%	175 – 300	$361,200
Container Handlers	9%	300 - 600	$844,700
Construction Loaders	17%	25 – 50	$90,600
Mobile Power Units	22%	75 - 100	$293,900
Transport Refrigeration Units	18%	25 - 50	$79,600

Emission reductions for each category are estimated as the exhaust emissions offset between a 2025-MY diesel engine and a battery-electric motor. The emission factors used for pieces of equipment in diesel-engine categories are shown in Table A-3, and those for pieces of equipment in zero-emission categories are shown in Table A-4.

Table A-3: CORE Diesel Emission Factors Per Equipment [kilograms/year]

Category	GHG	NO_x	PM2.5	ROG
Agricultural Tractors	22,540	75.9	0.3	3.8
Heavier Lift Forklifts	16,970	3.1	0.2	2.0
Container Handlers	192,940	38.8	2.8	45.2
Construction Loaders	5,110	18.8	0.1	1.2
Mobile Power Units	28,280	15.6	2.2	5.6
Transport Refrigeration Units	17,890	56.4	0.4	35.0

Table A-4: CORE Electric Emission Factors Per Equipment [kilograms/year]

Category	GHG	NO_x	PM2.5	ROG
Agricultural Tractors	6,690	0	0	0
Heavier Lift Forklifts	5,040	0	0	0
Container Handlers	57,300	0	0	0
Construction Loaders	1,520	0	0	0
Mobile Power Units	8,400	0	0	0
Transport Refrigeration Units	5,310	0	0	0

Based on recent CORE data, the average voucher incentive is projected to be $124,700 with about 75% of those vouchers going towards equipment domiciled in disadvantaged communities. Accounting for a 7% administrative cost, this projects to about 112 pieces of off-road equipment being incentivized by new CORE funding. CORE has a 3-year ownership requirement; therefore, total potential emission reductions due to new CORE funding are quantified over the course of 3 years.

Innovative Small e-Fleet

ISEF achieves emission reductions by helping small fleets and individual owner-operators pay up-front costs for zero-emission vehicles in classes 2B through 8. Over 80% of recent ISEF voucher requests have been for vehicles to reside in disadvantaged communities. A set voucher amount for each vehicle class is provided, but additional base voucher modifiers and voucher enhancements are available for fleet owners and single owner/operators that purchase fuel-cell electric vehicles or are in disadvantaged communities.

Based on historical ISEF data and recent trends, it is assumed that 55% of future voucher funding will go towards Class-6 through Class-8 trucks, with three quarters of these funds going towards Class-8 trucks. Furthermore, it is assumed that 22.5% of future voucher funding will go towards Class-3 trucks and 22.5% towards Class-4/5 trucks. The projected average emission factors for diesel and battery vehicles are shown in Table A-5.

From the proposed $14.97 million allocation for ISEF, an estimated 6% administrative cost, and the average voucher amount of $198,000, it is estimated that 71 vehicles will be funded. Because ISEF has a 3-year ownership requirement, projected emission reductions for ISEF are quantified for 3 years of vehicle operation. It is assumed for this analysis that all ISEF funded vehicles average 12,000 miles traveled per year.

Table A-5: ISEF Average Diesel and Battery Emission Factors [grams/mile]

Fuel	GHG	NO_X	PM2.5	ROG
Diesel	1,494	0.565	0.039	0.036
Battery	367	0	0.017	0

Zero-Emission Truck Loan Pilot

ZE-TLP builds on the highly successful legacy Truck Loan Program and is designed to provide continuity and consistency for eligible fleets and lenders. The project operates through a loan-loss reserve system and is open to qualified small trucking fleets with 20 or fewer vehicles purchasing new or used Class-2b through Class-8 zero-emission vehicles.

CARB partners with the California Pollution Control Financing Authority (CPCFA), part of the State Treasurer's Office, to participate in their California Capital Access Program (CalCAP) as an Independent Contributor. CalCAP provides day to day project administration. For each qualified zero-emission medium or heavy-duty vehicle loan made, CARB contributes 25% of the loan amount into a participating lender's loan-loss account that is held by a trustee. In the event of a qualifying loan default, the lender can request reimbursement for the principal loss from CPCFA, and the amount is deducted from the lender's account. With these funds available, lenders are better equipped to provide financing to businesses that need a little extra assistance, and typically offer more favorable terms than the business would qualify for otherwise.

The CARB FY 2022-23 Funding Plan allocated $5 million for the initial pilot. The project launched May 1, 2024, and is offered statewide. As of yet, there are limited project performance data with which to project emission reductions. In addition, the project has the potential to operate with effectively zero loss of funds. For these reasons, project metrics for the additional $5 million proposed with this FY 2024-25 Funding Plan are projected using a scenario similar to ISEF. In this way, a hypothetical benefit-cost score may be determined for ZE-TLP. The scenario used is that all loans default, half of the loans are $100,000 for Class-7 and Class-8 trucks, and the other half of loans are $43,000 for Class-4 through Class-6 trucks. It is also assumed that these vehicles only operate for 3 years at 12,000 miles traveled per year. For this given scenario, there are about 787 vehicles supported by ZE-TLP. The projected average emission factors for diesel and battery vehicles in this project scenario are shown in Table A-6.

Table A-6: ZE-TLP Average Diesel and Battery Emission Factors [grams/mile]

Energy	GHG	NO_X	PM2.5	ROG
Diesel	1,535	0.467	0.029	0.017
Battery	363	0	0.014	0

Section A-5: Quantified Program Metrics

Based on the assumptions stated above, the projected program metrics are quantified and tabulated here. Because CO_2 is the primary chemical product of combustion, the GHG reduction projections shown in Table A-7 and Table A-8 are far larger than the projected reductions of NO_X, PM2.5, and ROG. This effect carries over to the benefit-cost scores shown in Table A-9, where the benefit of reducing the mass of GHG emissions per funded dollar of program cost is relatively larger. The benefit-cost scores are not made for comparisons between different emission types, however. The benefit-cost scores are made to compare between projects for a given emission type, where a larger score is better.

Table A-7: Project Projections of Average Annual Metric Tons of GHG Emission Reductions Per Equipment and Average Annual Tons of Criteria Pollutant Emission Reductions Per Equipment

Project	GHG	NO_X	PM2.5	ROG
CORE	13.8	0.0523	0.0005	0.0141
ISEF	13.5	0.0075	0.0003	0.0005
ZE-TLP	14.1	0.0062	0.0002	0.0002

Table A-8: Project Projections of Metric Tons of GHG Emission Reductions, Tons of Criteria Pollutant Emission Reductions, and Numbers of Vehicles/Equipment

Project	GHG	NO_X	PM2.5	ROG	*N*
CORE	4,618	17.54	0.18	4.71	112
ISEF	2,881	1.59	0.06	0.10	71
ZE-TLP	33,232	14.60	0.48	0.54	787

Table A-9: Project Projections of Benefit-Cost Scores [grams/$]

Project	GHG	NO_X	PM2.5	ROG
CORE	309	1.063	0.011	0.285
ISEF	192	0.097	0.004	0.006
ZE-TLP	2,220	0.885	0.029	0.032

Table A-10: Project Projections of Full-Time Equivalent California Jobs Supported

Project	Total	Direct	Indirect	Induced
CORE	89.8	37.1	23.4	29.3
ISEF	79.5	31.8	17.2	30.4
ZE-TLP	26.0	11.3	6.1	8.5

Section A-6: Maximizing the Air Quality Improvement Program

CARB must provide preference in awarding funding to projects with higher benefit-cost scores that maximize the purposes and goals of the Air Quality Improvement Program. CARB may give additional preference based on the following criteria, as applicable, in funding awards to projects:

- Proposed or potential reduction of criteria or toxic air pollutants,
- Contribution to regional air quality improvement,

- Ability to promote the use of clean alternative fuels and vehicle technologies as determined by the state board, in coordination with the commission,
- Ability to achieve climate change benefits in addition to criteria pollutant or air toxic emissions reductions,
- Ability to support market transformation of California’s vehicle or equipment fleet to utilize zero-emission technologies, and
- Ability to leverage private capital investments.

Totaled across all three quantified criteria pollutants, AQIP projects are projected to have benefit-cost scores of 1,359 milligrams per dollar for CORE, 106 milligrams per dollar for ISEF, and 946 milligrams per dollar for ZE-TLP. CORE leads the way with benefit-cost score in large part due to its projected support of battery-electric agricultural tractors and transport refrigeration units. CORE supports many burgeoning zero-emission marketplaces in various categories of off-road equipment. Among the three AQIP projects, ZE-TLP is unique in its methodology and ability to leverage private capital. Through its loan-loss reserve system, funding may be replenished when truck loans are paid off, providing an opportunity to fund new loans. ISEF is tailored to help grow the zero-emission transport marketplace for small fleets and individual owner-operators. Though ISEF supports a similar distribution of truck classes as ZE-TLP, the differences in each program make a direct comparison of their benefit-cost scores challenging. ZE-TLP does not directly distribute funds to reduce the cost of zero-emission trucks as ISEF does. Also, ZE-TLP reserves per truck less funding than ISEF provides directly to the truck purchaser. All three projects are projected to achieve climate change benefits through their reductions of GHG emissions, and each are projected to support dozens of jobs. AQIP projects reduce NO_X emissions from the numbers one and two biggest contributors to poor regional air quality, diesel trucks and off-road equipment, respectively. They also promote and support zero-emission technologies.