Appendix B:
Emission Reductions Quantification Methodology

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Overview

In the Governor's budget for the 2020-21 fiscal year (FY), the California Air Resources Board (CARB) was appropriated $28.64 million for Air Quality Improvement Program (AQIP) projects. This appendix conservatively estimates the emission reductions of the project categories presented in the Funding Plan and provides additional details on the methodology developed and assumptions used. This analysis was guided by Assembly Bill (AB) 8 (Perea, Chapter 401, Statutes of 2013) and published Greenhouse Gas Reduction Fund (GGRF) quantification methodologies.[1]

It is important to note that these emission reduction estimates are illustrative examples of potential emission reductions that can be achieved with the funding allocated to these projects. Refined emission reduction estimates will be quantified as projects are implemented and data becomes available.

Emission Factor Development

To support the analysis of emission reductions from the proposed projects, staff developed a set of emission factors for a variety of different vehicle classes. The emission factors and assumptions used in the analysis were derived from a number of sources such as CARB's California-modified Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (CA-GREET 3.0) Model,[2] CARB's Emission Factor (EMFAC2017) Model,[3] CARB regulation staff reports and emissions inventories, publically available technical reports, and staff assumptions. Greenhouse gas (GHG) emission factors were developed on a well-to-wheel (WTW) basis since greenhouse gases are global pollutants. Criteria pollutant and toxic emission factors are calculated based solely on tailpipe emissions because of their localized impact.

Staff developed emission factors for the following vehicle classes:

- Light-duty vehicles (LDV);
- Medium heavy-duty vehicles (MHD);
- Heavy heavy-duty vehicles (HHD);
- Urban buses;
- School buses;
- Cargo-handling equipment (CHE);
- Transport refrigeration units (TRU); and
- Locomotives.

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[1] Cap-and-Trade auction proceeds quantification materials are available https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/quantification.htm.
[2] http://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet.htm
[3] https://www.arb.ca.gov/emfac/2017/

GHG Emission Factors

Fuel economy is an important component of the GHG emission reduction analysis, as the value determines the emissions generated based on the consumption of each unit of fuel for the miles traveled or for off-road applications, unit of fuel consumed per hour of use. Fuel economy values were derived from EMFAC2017[4] and CARB's off-road mobile source emissions inventories[5], specifically the 2011 Cargo Handling Equipment Inventory, the 2011 TRU Emissions Inventory models, and the 2017 Off-road Diesel Emissions Inventory. Table B-1 provides a summary of the fuel economy values for baseline gasoline or diesel on-road vehicles, while Table B-2 provides a summary of fuel economy values for baseline diesel off-road vehicles. These values were used in the analysis for conventional vehicles.

Table B-1: On-Road Fuel Economy Values of Baseline Conventional Vehicles

Vehicle Class	Fuel Type	Fuel Economy Values (mpg)		
		2000	2017	2020
LDV	Gasoline	24.0	32.3	35.5
MHD	Diesel	-	-	10.4
HHD	Diesel	-	-	7.40
Urban Bus	Diesel	-	-	7.47
School Bus	Diesel	-	-	9.27

Table B-2: Off-Road Fuel Economy Values of Baseline Diesel Vehicles

Vehicle Class	Horsepower	Fuel Economy
		Tier 4 Final
Forklift	100-174	1.4
Yard Truck	175-299	3.5
TRU	23-25	0.7
Railcar Movers	130-350	5.0

The fuel economy was paired with carbon intensity (CI) values from the Low Carbon Fuel Standard (LCFS)[6] and the lower heating value (LHV) of applicable fuels to calculate the WTW GHG emission factor for each project type, as shown in Formula 1. This was done so that the upstream (well-to-tank) emissions of the fuel were representative of the fuel used, paired with an illustrative potential technology. For on-road vehicles, the GHG emission factor is in units of grams of carbon dioxide (CO2) equivalent per mile (gCO2e/mi), and for off-road vehicles, the GHG emission factor is in units of grams of CO2e per hour (gCO2e/hr).

[4] https://www.arb.ca.gov/emfac/2017/
[5] https://www.arb.ca.gov/msei/msei.htm
[6] https://www.arb.ca.gov/fuels/lcfs/lcfs.htm

Formula 1: GHG Emission Factors

$$GHG\ Emission\ Factor\ \left(\frac{gCO2e}{mi}\ or\ \frac{gCO2e}{hr}\right) = \frac{LCFS\ carbon\ intensity * LHV\ of\ fuel}{fuel\ economy\ of\ vehicle}$$

For alternative-fueled vehicles, the baseline fuel economy values were converted for a given alternative fuel, using LHVs of the baseline and alternative fuels and the energy economy ratio (EER) value, as shown in Formula 2. EER values were derived from the LCFS Regulation[7] or based on a study on the energy efficiency of battery-electric vehicles compared to conventional diesel vehicles operating on the same duty cycle.[8]

Formula 2: Alternative Fuel Vehicle Economy

$$Alt.\ Fuel\ Vehicle\ Economy\ \left(\frac{miles}{fuel\ unit}\ or\ \frac{hours}{fuel\ unit}\right)$$
$$= fuel\ economy_{baseline} * \frac{LHV_{alt.\ fuel}}{LHV_{baseline\ fuel}} * EER$$

Carbon intensity values used can be found in the California Climate Investments (CCI) Emission Factor Database[9]. Low Carbon Fuel Standard (LCFS) carbon intensity values for gasoline, diesel, CNG, and electricity are derived from Lookup Table 7-1 in CARB's Final Regulation Order[10].

It should be noted that as more renewables are introduced into the transportation fuel mix, lowering the average CI of the fuel, additional GHG benefits may be achieved, which may lower the emission factors. As the fuel mix changes, staff will reflect those changes in future analyses.

Criteria Pollutant and Toxics Emission Factors

For the determination of tailpipe criteria pollutant emission factors for on-road vehicles, staff used CARB's EMFAC2017 model to calculate the tailpipe emissions and emissions associated with the usage of the supported vehicles or equipment, such as idling emissions and PM 2.5 emissions from brake and tire wear, when applicable. For off-road equipment, staff used CARB's 2011 Cargo Handling Equipment Inventory, the 2011 TRU Emissions Inventory, and the 2017 Off-road Diesel Emissions Inventory to develop emission factors associated with the usage of the supported vehicles or equipment.

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[7] https://www.arb.ca.gov/regact/2015/lcfs2015/lcfsfinalregorder.pdf

[8] https://ww2.arb.ca.gov/sites/default/files/2018-10/170425eerdraftdocument.pdf

[9] https://ww2.arb.ca.gov/resources/documents/cci-quantification-benefits-and-reporting-materials

[10] https://ww3.arb.ca.gov/regact/2018/lcfs18/frolcfs.pdf

As discussed in previous funding plans, preliminary data show that attaching a hybrid driveline to a vehicle without careful integration with the engine and after-treatment system can have the unintended consequence of increasing criteria pollutant emissions. Subsequently, the emission factors for hybrids are based on a certified vertically integrated hybrid vehicle. Moreover, improved fuel economy from the use of a hybrid system[11] provides improvements in the emission factors as less fuel is used and the well-to-tank GHG emissions are reduced.

Staff incorporated deterioration, when available, for both on-road and off-road vehicles. Staff also applied a 50 percent reduction in brake wear emissions for on-road vehicles that implement regenerative braking capability.[12] The emission factors developed for advanced technology vehicles are supported by the proposed projects when appropriate, along with emission factors for baseline conventional vehicles.

Additionally, the vehicle or equipment's load factor, which is an indicator of the nominal amount of work done by the engine for a particular application, and the horsepower rating of the engine are included when developing emission factors for off-road projects.

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[11] Hybrid vehicle fuel economy improvement based on Climate Change Scoping Plan Appendices, Volume I: Supporting Documents and Measure Detail.
http://www.arb.ca.gov/cc/scopingplan/document/appendices_volume1.pdf

[12] NREL, BAE/Orion Hybrid Electric Buses at New York City Transit, http://www.afdc.energy.gov/pdfs/42217.pdf, March 2008

AB 8

AB 8 extended the funding for AQIP through 2023, refined the evaluation criteria for projects supported by AQIP, and introduced the following requirements that staff followed to develop the project scoring criteria:

- The state board shall provide preference in awarding funding to those projects with higher benefit-cost scores that maximize the purposes and goals of the Air Quality Improvement Program.[13]
- "Benefit-cost score" means the reasonably expected or potential criteria pollutant emission reductions achieved per dollar awarded by the Board for the project.[14]
- The state board also may give additional preference based on the following criteria, as applicable, in funding awards to projects:[15]

  1. Proposed or potential reduction of criteria or toxic air pollutants.
  2. Contribution to regional air quality improvement.
  3. Ability to promote the use of clean alternative fuels and vehicle technologies as determined by the state board, in coordination with the Energy Commission.
  4. Ability to achieve climate change benefits in addition to criteria pollutant or air toxic emission reductions.
  5. Ability to support market transformation of California's vehicle or equipment fleet to utilize low carbon or zero-emission technologies.
  6. Ability to leverage private capital investments.

Statute directs CARB to annually evaluate potential project categories to assign preference for AQIP funding, based upon the specific criteria identified above. The analysis and methodology in this section of the appendix describes the implementation of the provisions that require CARB to assign preference to projects with a higher benefit-cost score. This AB 8 analysis is fully executed for the three projects that may be funded through AQIP: Clean Cars 4 All (formerly known as Enhanced Fleet Modernization Program, or EFMP, Plus-Up Pilot Project), the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project, and Clean Off-Road Equipment Voucher Incentive Project.

Overview

Conservative estimates for criteria pollutant and toxic air contaminants were developed using guidance provided in AB 8. Because criteria pollutant and toxic air contaminant emissions are geographically localized, criteria pollutant and toxic air

[13] Health & Safety Code Section 44274(b)
[14] Health & Safety Code Section 44270.3(e)(1)
[15] Health & Safety Code Section 44274(b)

contaminant emissions reductions reported in this appendix are estimated at the tailpipe. This section of the appendix provides information on the following:

- Quantification
- Benefit-Cost Score Analysis;
- Additional Preference Criteria Scores; and
- Total Benefit Index Scores.

Quantification

To quantify the potential emission reductions for each project, staff must first determine the annual per-vehicle emission reductions for each technology weighted by the amount of each technology funded in the project. Once the annual per-vehicle emission reductions are determined, staff estimate the average project costs to determine the number of vehicles or equipment that may be funded by the allotted funding amounts. Finally, to determine the total potential emission reductions for each project, the average annual per-vehicle emission reductions is multiplied by the number of vehicles or equipment funded and the project life. Due to the uncertainty in the vehicle and equipment types that will be funded, staff have quantified emission reductions based on an illustrative example. As noted at the beginning of this Appendix, CARB was appropriated $28.64 million for AQIP. After doing a cost-benefit analysis and considering project need, staff propose to allocate $25 million in AQIP funds to Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project and $3 million to Clean Cars 4 All. The remaining $0.64 million of AQIP funds would be placed in a reserve for fiscal uncertainty. The AQIP appropriation is based off projected motor vehicle fee revenue. Due to current market uncertainty, it is a prudent step to establish this reserve, and CARB has taken this measure before when there was revenue uncertainty. Staff will evaluate revenue in early 2021. If revenue is sufficient, CARB will allocate the $0.64 million, or however much is available, according to project need and will hold additional public workgroups to discuss this allocation as necessary.

Annual Per-Vehicle Emission Reductions

Annual emission reductions are first calculated for each eligible or representative technology in the project using the emission factors that have been developed for each project. Annual emission reductions are in units of tons per year (tpy) for the emissions reduced and are calculated by taking the difference in emission rates between the baseline vehicle and advanced technology vehicle and then multiplying by usage. This value is then converted from grams per year to metric tons per year for GHG emissions and U.S. tons per year for criteria pollutants and toxic air contaminants.

For on-road projects, annual emission reductions are calculated using Formula 3, where emission factors are in terms of grams per mile (g/mi) and usage is based on annual vehicle miles traveled (VMT) or miles per year (mi/yr). For off-road projects, annual emission reductions are also calculated using Formula 3, however, emission factors are in terms of grams per hour (g/hr) and usage is in terms of hours per year.

Formula 3: Annual Per-Vehicle Emission Reductions

$$Annual\ Per\ Vehicle\ Emission\ Reductions\ (tpy) = (EF_{baseline} - EF_{ATV}) * Usage$$

Once the annual per-vehicle emission reductions are calculated for the eligible technologies in each project, technology splits are factored in so that the emission reductions on a per-vehicle basis are representative of an average vehicle or equipment replaced under the project, as shown in Formula 4. The technology splits or mix for each project are determined based on historical project data or projected demand.

Formula 4: Average Annual Per-Vehicle Emission Reductions

$$Average\ Annual\ Per\ Vehicle\ Emission\ Reductions\ (tpy) = \sum (annual\ emission\ reductions\ per\ vehicle\ type * fraction\ of\ vehicles\ funded)$$

<u>Project Costs</u>

Once staff have identified the incentive cost for each technology and potential technology split for a given project, staff can calculate the average incentive amount for each project, using Formula 5.

Formula 5: Average Incentive Cost

$$Average\ Incentive\ Cost\ (\$) = \sum (cost\ per\ vehicle\ type * fraction\ of\ vehicles\ funded)$$

Once the average incentive amount is determined, the allotted funding for the project minus the administrative cost can be divided by the average incentive amount to estimate the number of vehicles or equipment likely to be funded, as shown in Formula 6. Staff evaluated the appropriate administrative cost for each project, which vary depending on the amount of oversight necessary to implement the project.

Formula 6: Number of Vehicles Funded

$$Number\ of\ Vehicles\ Funded = \frac{(Proposed\ Funding\ Allocation - Administrative\ Cost)}{Average\ Incentive\ Cost}$$

Total Lifetime Emission Reductions

Once the average per-vehicle emission reductions are determined, it is multiplied by the potential number of vehicles funded and the project life to determine the total potential lifetime emission reductions for a project, as shown in Formula 7.

Formula 7: Lifetime Emission Reductions

$$Lifetime\ Emission\ Reductions\ (tons) = average\ per\ vehicle\ emission\ reductions * number\ of\ vehicles * project\ life$$

Proposed Project Quantification

Clean Cars 4 All (CC4A)

Clean Cars 4 All (CC4A), also known as EFMP Plus-Up, achieves emission reductions by incentivizing the scrap and replacement of old, high-emitting vehicles with cleaner advanced technology vehicles. To calculate the emission reductions for this project, staff used past project data to determine the model year of the baseline vehicle and the replacement vehicle. Based on project data from the 2020 calendar year, on average, a 2000 vehicle model year was scrapped and replaced by a 2017 model year advanced technology vehicle.

Project data for the life of the program shows that 12 percent of the funding went to battery-electric vehicle (BEV) purchases, 55 percent went to plug-in hybrid electric vehicle (PHEV) purchases, and the remaining 33 percent went to conventional hybrid vehicle purchases. Less than 0.2% of funding went to fuel cell electric vehicles; as a result, staff did not quantify potential reductions for future purchases for FY 2020-21. For the purposes of this analysis, staff assumed that FY 2020-21 AQIP funding would continue to incentivize those technologies at similar rates. Table B-3 reflects the emission factors for the selected baseline, conventional hybrid, plug-in hybrid, and battery electric vehicles. For more information on how these emission factors were developed, please see the Emission Factor Development section at the beginning of this Appendix.

Table B-3: CC4A Emission Factors

Pollutant	2000 Gasoline (g/mi)	2017 Conventional Hybrid Vehicle (g/mi)	2017 Plug-in Hybrid Electric Vehicle (g/mi)	2017 Battery Electric Vehicle (g/mi)
NOx	0.1914	0.0167	0.0100	0
PM 2.5	0.0208	0.0115	0.0109	0.0099
ROG	0.0384	0.00335	0.0021	0
GHG	479	285	205	86

Staff generated vehicle usage assumptions for CC4A through literature review for each of the vehicle types evaluated. The annual usage assumptions for CC4A are shown in the table below.

Table B-4: CC4A Annual Usage Assumptions

Technology	Usage (mi/yr)
PHEV/Conventional Hybrid	14,855[16]
BEV	11,059[17]

Using the emission factors, technology mix, and the annual usage assumptions above, staff calculated the potential annual per-vehicle emission reductions for CC4A, as shown in Table B-5.

Table B-5: CC4A Annual Emission Benefits on a Per-Vehicle Basis

Pollutant	Supported Technologies	Per Vehicle Annual Emission Reductions (tpy)	
		Per Technology	Average
GHG	Conventional Hybrid	2.88	3.71
	PHEV	4.07	
	BEV	4.35	
NOx	Conventional Hybrid	0.00286	0.00286
	PHEV	0.00297	
	BEV	0.00233	
PM 2.5	Conventional Hybrid	0.00015	0.00016
	PHEV	0.00016	
	BEV	0.00013	
ROG	Conventional Hybrid	0.00057	0.00057
	PHEV	0.00059	
	BEV	0.00047	

Based on past project data, staff anticipate the average incentive amount to be $8,900. If $25 million of the available AQIP funds were to go to CC4A, staff estimate that approximately 2,400 vehicles can be funded. Staff anticipate using $3 million of the available AQIP funds for CC4A; CARB and the Legislature are committed to reducing emissions in low-income households and priority communities. For the purpose of this analysis, staff estimate that the remaining useful life of the baseline, 2000 model year vehicle is 3 years, therefore, emission reductions are quantified over the course of 3 years. The total potential emission reductions for an allocation of

[16] Based on 40.7 miles per day. Smart, J., Powell, W., and Schey, S., "Extended Range Electric Vehicle Driving and Charging Behavior Observed Early in the EV Project," SAE Technical Paper 2013-01-1441, 2013, doi:10.4271/2013-01-1441. (http://papers.sae.org/2013-01-1441/)

[17] Based on 30.3 miles per day. Smart, J. and Schey, S., "Battery Electric Vehicle Driving and Charging Behavior Observed Early in The EV Project," *SAE Int. J. Alt. Power.* 1(1):27-33, 2012, doi:10.4271/2012-01-0199. (http://papers.sae.org/2012-01-0199/)

$3 million (minus project implementation costs) for the project is quantified over the course of 3 years and is shown in Table B-6.

Table B-6: Total Potential Emission Reductions for CC4A

Pollutant	Per Vehicle Average Annual Emission Reductions (tpy)	Number of Vehicles	Average Annual Emissions Reductions (tpy)	Project Life (years)	Lifetime Annual Emission Reductions (tons)
GHG	3.71	286	1,061	3.0	3,183
NOx	0.00286		0.82		2.45
PM 2.5	0.00016		0.04		0.13
ROG	0.00057		0.16		0.49

<u>Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP)</u>

The Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) is the cornerstone of CARB's advanced technology heavy-duty incentives, providing funding since 2009 to support the long-term transition to ZEVs in the heavy duty market, as well as supporting investments in other emerging technology. HVIP achieves emission reduction benefits by reducing the up-front cost of hybrid or zero-emission trucks and buses, allowing fleet owners to secure a voucher through their local dealer as part of their vehicle purchase. For the purposes of this analysis, staff estimated reductions from the emissions offset between a new, 2020 model year conventional truck or bus, and an advanced technology vehicle. To illustrate the potential magnitude of emission reductions in this Funding Plan, staff assumed the $25 million of available AQIP funds were used for HVIP.

Based on future voucher request projections, staff assumed that 27 percent of vouchers would go towards the purchase of MHD battery-electric trucks, 15 percent for HHD battery-electric trucks, 42 percent for battery-electric urban buses, 13 percent for battery-electric school buses, and approximately 3 percent for electric power takeoff (ePTO) systems. While HVIP has provided vouchers for fuel cell electric vehicles, they currently comprise a small portion of participation and were left out of this analysis. Additionally, while HVIP funds plug-in hybrid electric vehicles, there are currently none eligible in HVIP and so they were also not included.

For baseline urban bus emission factors, staff used an average of diesel and CNG urban bus emission rates since the current California fleet utilizes a mix of the two fuel types. Only limited data is available for heavy-duty CNG-fueled vehicles, therefore, staff assumed CNG vehicles have similar emission rates as diesel-fueled vehicles because they are certified to the same emission standard.

Based on discussions with manufacturers, ePTO systems automatically prevents engine idle by shutting the engine off while in park or neutral, preventing unnecessary engine usage during PTO operation. For emission factors associated with ePTOs, staff utilized the emission factors found in EMFAC2017 to quantify the emissions reduction associated with ePTO systems that are currently eligible in HVIP. The emission factor used is associated with the excess emissions due to the usage of PTOs powered by a diesel engine. Emission factors for HVIP are shown in Table B-7 and emission factors used to quantify PTOs are shown in Table B-8. For more information on how these emission factors were developed, please see the Emission Factor Development section at the beginning of this Appendix.

Table B-7 : HVIP Emission Factors

Vehicle Class	Pollutant	2020 Diesel (g/mi)	2020 CNG (g/mi)	2020 BEV (g/mi)
MHD	NOx	1.450		0
	PM 2.5	0.066		0.031
	ROG	0.011		0
	GHG	1,297		195
HHD	NOx	2.522		0
	PM 2.5	0.057		0.022
	ROG	0.050		0
	GHG	1,825		274
Urban Bus	NOx	0.700	0.700	0
	PM 2.5	0.048	0.048	0.025
	ROG	0.011	0.011	0
	GHG	1,807	1,761	271
School Bus	NOx	1.753		0
	PM 2.5	0.327		0.163
	ROG	0.016		0
	GHG	1,458		219

Note: MHD and HHD emission factors are based on population-weighted averages of the T6 and T7 diesel vehicle classes in EMFAC2017, respectively, excluding out-of-state vehicles.

Table B-8: ePTO Emission Factors

Vehicle Class	Pollutant	2020 Diesel (g/hr)	2020 Battery Electric (g/hr)
ePTO	NOx	72.840	0
	PM 2.5	0.069	0
	ROG	0.417	0
	GHG	32,445	5,899

For urban buses, staff used data provided by previous HVIP voucher recipients to determine the average annual usage. Data for ePTO systems were obtained from NREL's Fleet Test and Evaluation Team.[18] Based on the information, staff assumed

[18] https://www.nrel.gov/transportation/assets/pdfs/67116.pdf

that a vehicle typically operates in PTO mode for 4 hours a day and 250 workdays a year. Additionally, staff assumed the fuel consumption rate of 3.218 gallons per hour for ePTO systems based on data from EMFAC2017. For all other battery-electric vehicle classifications, the annual usage assumption was based on the California Hybrid, Efficient and Advanced Truck Research Center (CalHEAT) Research Center's report on "Battery Electric Parcel Delivery Truck Testing and Demonstration."[19] The annual usage assumptions for HVIP are shown in Table B-9.

Table B-9: HVIP Annual Usage Assumptions

Vehicle Class	Technology	Usage (mi/yr)
MHD	BEV	12,000
HHD	BEV	12,000
	ePTO	1,000 hours/yr
Urban Bus	BEV	30,000
School Bus	BEV	12,000

Using the emission factors, technology mix, and the annual usage assumptions above, staff calculated the potential annual per-vehicle emission reductions for HVIP, as shown in Table B-10

[19] Gallo, Jean-Baptiste, Jasna Tomić. (CalHEAT). 2013. Battery Electric Parcel Delivery Truck Testing and Demonstration. California Energy Commission.

Table B-10: HVIP Annual Emission Benefits on a Per-Vehicle Basis

Pollutant	Vehicle Class	Supported Technologies	Per Vehicle Annual Emission Reductions (tpy)	
			Per Technology	Average
GHG (metric tons CO_2e per year)	MHD	BEV	13.228	32.52
	HHD	BEV	18.617	
		ePTO	26.546	
	Urban Bus	BEV	53.518	
	School Bus	BEV	14.868	
NOx	MHD	BEV	0.0174	0.028
	HHD	BEV	0.0303	
		ePTO	0.0728	
	Urban Bus	BEV	0.0210	
	School Bus	BEV	0.0210	
PM 2.5	MHD	BEV	0.0004	0.0007
	HHD	BEV	0.0004	
		ePTO	0.0001	
	Urban Bus	BEV	0.0007	
	School Bus	BEV	0.0020	
ROG	MHD	BEV	0.0001	0.0003
	HHD	BEV	0.0006	
		ePTO	0.0004	
	Urban Bus	BEV	0.0003	
	School Bus	BEV	0.0002	

Applying the proposed voucher amounts and the forecasted technology mix, staff calculated the average voucher cost for HVIP as shown in Table B-11.

Table B-11: HVIP Average Incentive Cost

Vehicle Class	Supported Technologies	Cost Per Technology	Average
MHD	BEV	$63,000	$115,000
HHD	BEV	$126,000	
	ePTO	$30,000	
Urban Bus	BEV	$150,000	
School Bus	BEV	$207,900	

Heavy-duty trucks can have a useful life of over 20 years[20] and the average school bus has a useful life of 15 years.[21] Therefore, staff assumed a conservative project life of 15 years and quantified HVIP's total potential emission reductions over the course of 15 years, as shown in Table B-12 below. The number of vehicles was estimated by taking the assumed $25 million (minus program implementation costs) and dividing it by the average incentive cost found in Table B-11.

Table B-12: Total Potential Emission Reductions for HVIP

Pollutant	Per Vehicle Average Annual Emission Reductions (tpy)	Number of Vehicles	Average Annual Emissions Reductions (tpy)	Project Life (years)	Lifetime Annual Emission Reductions (tons)
GHG	32.52	200	6,557	15	98,400
NOx	0.0281		6		84.9
PM 2.5	0.0007		0		2.08
ROG	0.0003		0		0.84

Clean Off-Road Equipment Voucher Incentive Project (CORE)

The Clean Off-Road Equipment Voucher Incentive Project (CORE) achieves emission reduction benefits by accelerating deployment of cleaner off-road technologies. It provides a streamlined way for fleets ready to purchase specific zero-emission equipment to receive funding. This project specifically targets zero-emission off-road freight equipment that is currently in the early stages of commercial deployment. Eligible project types include on and off-road terminal tractors (i.e., yard trucks), transport refrigeration units (TRUs), forklifts, container handling equipment, airport cargo loaders, wide-body aircraft tugs, railcar movers, rubber-tired gantry cranes, among others. Because this project includes a variety of eligible types of vehicles, equipment, and technologies, it is important to note that this analysis is an illustrative example of the potential emission reductions that may be achieved through this project. To estimate the potential magnitude of emission reductions in this Funding Plan, staff assumed the $25 million of available AQIP funds were to be used for CORE.

For this analysis, staff estimated the potential reductions for four project types that are likely to be the majority under this project: yard trucks, forklifts, TRUs, and railcar movers. Emission factors for these project types are shown in Table B-13.

[20] Energy Research and Development Division: Final Project Report – prepared for California Energy Commission. CalHEAT Truck Research Center. August 2013.
[21] https://www.afdc.energy.gov/uploads/publication/case-study-propane-school-bus-fleets.pdf

Table B-13: CORE Emission Factors

Vehicle Class	Pollutant	Tier 4 Final Diesel (g/hr)	BEV (g/hr)
Forklift	NOx	0.781	0
	PM 2.5	0.281	0
	ROG	1.748	0
	GHG	19,303	4,193
Yard Truck	NOx	8.238	0
	PM 2.5	0.484	0
	ROG	4.271	0
	GHG	47,150	7,077
TRU	NOx	47.26	0
	PM 2.5	1.699	0
	ROG	36.85	0
	GHG	8,863	1,330
Railcar Mover	NOx	8.000	0
	PM 2.5	0.552	0
	ROG	4.052	0
	GHG	51,200	10,137

Staff generated annual usage assumptions using CARB's cargo handling equipment (CHE) inventory model for forklifts and yard trucks, the TRU inventory model for TRUs, and programmatic minimum thresholds, as shown in Table B-14.

Table B-14: CORE Annual Usage Assumptions

Vehicle Class	Usage (hrs/yr)
Forklift	800
Yard Truck	2,400
TRU	1,300
Railcar Mover	800

Applying the emission factors and usage assumptions above, staff calculated the potential annual per-vehicle emission reductions for the Clean Off-Road Equipment Voucher Incentive Project as shown in Table B-15.

Table B-15: CORE Annual Emission Benefits on a Per-Vehicle Basis

Pollutant	Vehicle Class	Supported Technologies	Per Vehicle Annual Emission Reductions (tpy)
GHG	Forklift	BEV	12.09
	Yard Truck	BEV	96.18
	TRUs	BEV	9.79
	Railcar Mover	BEV	32.85
NOx	Forklift	BEV	0.0006
	Yard Truck	BEV	0.0198
	TRUs	BEV	0.0614
	Railcar Mover	BEV	0.0064
PM 2.5	Forklift	BEV	0.0002
	Yard Truck	BEV	0.0012
	TRUs	BEV	0.0022
	Railcar Mover	BEV	0.0004
ROG	Forklift	BEV	0.0014
	Yard Truck	BEV	0.0103
	TRUs	BEV	0.0479
	Railcar Mover	BEV	0.0032

For this analysis, staff looked at the voucher requests to-date and made assumptions that forklifts, yard trucks, TRUs, and railcar movers would receive about 13%, 56%, 20%, and 11% of the funding, respectively. The expected cost per technology for the four project types are shown in Table B-16

Table B-16: CORE Average Incentive Cost

Vehicle Class	Supported Technologies	Cost Per Technology
Forklift	BEV	$221,000
Yard Truck	BEV	$172,000
TRU	BEV	$80,000
Railcar Mover	BEV	$277,000

Based on the expected cost per technology and the aforementioned funding portions for each vehicle class, staff expect that about 13 forklifts, 75 yard trucks, 57 TRUs, and 10 railcar movers could be funded if CORE were allocated the $25 million. The resulting total emission reductions is outlined in Table B-17.

Table B-17: Total Potential Emission Reductions for CORE

Pollutant	Vehicle Class	Per Vehicle Annual Emission Reductions (tpy)	Number of Vehicles	Annual Emission Reductions (tpy)	Project Life (years)	Lifetime Emission Reductions Per Vehicle Class (tons)	Project Total Lifetime Emission Reductions (tons)
GHG	Forklift	12.0875	13	158	10	1,579	82,800
	Yard Truck	96.1756	75	7,254		72,543	
	TRUs	9.7924	57	558		5,583	
	Railcar Mover	32.8503	10	312		3,122	
NOx	Forklift	0.0006	13	0.008		0.082	51
	Yard Truck	0.0198	75	1.491		14.912	
	TRUs	0.0614	57	3.503		35.030	
	Railcar Mover	0.0064	10	0.061		0.608	
PM 2.5	Forklift	0.0002	13	0.003		0.029	2
	Yard Truck	0.0012	75	0.088		0.876	
	TRUs	0.0022	57	0.126		1.259	
	Railcar Mover	0.0004	10	0.004		0.042	
ROG	Forklift	0.0014	13	0.018		0.183	36
	Yard Truck	0.0103	75	0.773		7.732	
	TRUs	0.0479	57	2.731		27.313	
	Railcar Mover	0.0032	10	0.031		0.308	

Benefit-Cost Score Analysis

Staff analyzed the expected costs and developed cost-effectiveness values for each AQIP-funded project using well-established cost-effectiveness calculation methodology for incentives, consistent with that used in the Carl Moyer Memorial Air Quality Standards Attainment Program (Carl Moyer Program). In addition, to calculate cost-effectiveness, staff also applied an appropriate discount rate and utilized a capital recovery factor (CRF) in the analysis based on 2017 Carl Moyer Program Guidelines.[22] The one percent discount rate was used and the corresponding CRF was determined based on the assumed usage life of the vehicles or equipment supported by a given project.

For each of the proposed projects funded by AQIP, a cost-effectiveness value was calculated. The cost-effectiveness of a project is determined using Formula 8 below.

[22] https://www.arb.ca.gov/msprog/moyer/guidelines/2017gl/2017_cmp_gl_volume_1.pdf

Formula 8: Cost-Effectiveness

$$Cost\ Effectiveness\left(\frac{\$}{ton}\right) = \frac{Incentive\ Amount\ per\ Vehicle\ or\ Equipment * CRF}{Annual\ Per\ Vehicle\ Weighted\ Emission\ Reductions}$$

Weighted emission reductions are calculated using Formula 9, consistent with Carl Moyer Program Guidelines:

Formula 9: Annual Weighted Emission Reductions

$$Annual\ Weighted\ Emission\ Reductions\left(\frac{weighted\ tons}{year}\right) = NOx\ reductions + ROG\ reductions + (20 * PM\ reductions)$$

Table B-18 provides the inputs and the resulting weighted criteria pollutant and toxic air contaminant cost-effectiveness, in terms of dollars per ton of weighted emission reductions, for projects that may be funded by AQIP. Using a cost-benefit analysis, staff is evaluating the efficacy of using AQIP funds for three programs: CC4A, HVIP, or CORE.

Table B-18: AB 8 Analysis – Weighted Criteria Pollutant and Toxic Air Contaminant Cost-Effectiveness

Proposed Project	Project Life	CRF	Average Annual Per-Vehicle Weighted Emission Reductions (tpy)	Average Incentive Cost	Cost-Effectiveness ($/ton)
CC4A	3	0.508	0.01	$8,915	$692,565.58
HVIP	15	0.072	0.0421	$125,000	$213,851.43
CORE	10	0.106	0.0631	$133,00	$222,457.95

The cost-effectiveness values for each project were given points based on a scale of one to five points. The bins were determined by taking the high and low resulting benefits and scaled to develop an equal distribution of scores. Those projects with a cost-effectiveness of less than $50,000 per ton of weighted emission reductions received a high of five points. The remaining bins were increased by $50,000 increments with the least cost-effective projects, those projects that cost over $200,000 per weighted ton of emissions reduced, receiving the lowest points possible. The cost-effectiveness of each proposed project was scored based on the following scale:

5: Less than $50,000 per ton
4: $50,000 to $99,999 per ton
3: $100,000 to $149,999 per ton

2: $150,000 to $199,999 per ton
1: $200,000 per ton or more

The resulting scores from the scale shown above were then used in the "Total Benefit Index" for AB 8 project selection. Finally, per AB 8, the cost-effectiveness values were converted to benefit-cost values based on pound of weighted emission reductions per dollar spent. The cost-effectiveness, benefit-cost value, and resulting score of each of the proposed projects are shown in Table B-19.

Table B-19: AB 8 Analysis – Benefit-Cost Value and Score for Total Benefit Index

Proposed Project	Cost-Effectiveness ($/ton)	Benefit-Cost Value (lbs/$)	Benefit-Cost Score
CC4A	$692,565.58	0.00288	1
HVIP	$213,851.43	0.00935	1
CORE	$222,457.95	0.00899	1

Additional Preference Criteria

Per AB 8, additional preference criteria may be used to provide additional funding preference in conjunction with the benefit-cost scores summarized in Table A-11. The additional preference criteria includes:

- Proposed or potential reduction of criteria and toxic air pollutants;
- Contribution to regional air quality improvement;
- Ability to promote the use of clean alternative fuels and vehicle technologies;
- Ability to achieve GHG reductions;
- Ability to support market transformation of California's vehicle or equipment fleet to utilize low carbon or zero-emission technologies; and
- Ability to leverage private capital investments.

Recognizing the range of potential benefits and to ensure a robust mix of proposed projects to be funded, staff analyzed the associated data and equally divided the results into scores between 0 and 5 for quantitative preference criteria. The quantitative preference criteria for each project includes the proposed or potential reduction of criteria and toxic air pollutants, contribution to regional air quality, and the ability to achieve GHG reductions. Staff used the following steps to develop scoring scales and final scores for the quantitative preference criteria:

1. Quantify the results for each additional preference criteria for the proposed projects;
2. Establish scoring scale increments to generate an equal distribution in points for the proposed projects; and
3. Rank the proposed projects based on the established scoring scale, which is then used in the "Total Benefit Index."

Staff anticipate that the scales for the quantitative additional preference criteria may change each year depending on the mix of projects proposed, due to differences in the range of expected benefits or when additional information becomes available to refine the evaluation. The data and rationale used to establish each of the criteria weighting factors for the associated scores are described below.

Proposed or Potential Reduction of Criteria or Toxic Air Pollutants

This analysis considered the magnitude of emission reductions by quantifying the direct criteria pollutant and toxic air contaminant emission reductions expected per average vehicle or equipment supported under each project. With the benefit-cost score analysis primarily driven by overall project incentive amounts, this additional criteria allowed staff to make direct comparisons of the emission reductions expected by the different proposed projects, independent of the associated incentive amounts.

For this additional preference criterion, staff analyzed the emission benefits on a per-vehicle basis to account for the differences in vehicle sales volumes and statewide populations of the various vehicles supported by AQIP. Resulting total lifetime emission reductions ranged from less than one ton to almost three tons of lifetime criteria pollutant and toxic air contaminant emission reductions per-vehicle. The scoring scale for this criterion was established by evaluating the range of lifetime tons of emission reductions between the highest and lowest value to try to have an equal distribution of scores. As a result, the bins were scaled in half ton increments. Projects with less than or equal to one ton of criteria pollutant and toxic air contaminant emission reductions received one point, while those projects with greater than two and a half tons of criteria pollutant and toxic air contaminant emission reductions received a score of five points. The resulting scale for criteria pollutant and toxic air contaminant emission reductions on a per-vehicle basis is shown below.

5: Greater than 2.5 tons of criteria and toxic emission reductions per vehicle
4: 2 to 2.49 tons of criteria and toxic emission reductions per vehicle
3: 1.5 to 1.99 tons of criteria and toxic emission reductions per vehicle
2: 1 to 1.49 tons of criteria and toxic emission reductions per vehicle
1: Less than 1 ton of criteria and toxic emission reductions per vehicle

Based on the information described above, Table B-20 summarizes the results and the corresponding score for this additional preference criterion.

Table B-20: AB 8 Analysis – Potential Reduction of Criteria or Toxic Air Pollutants

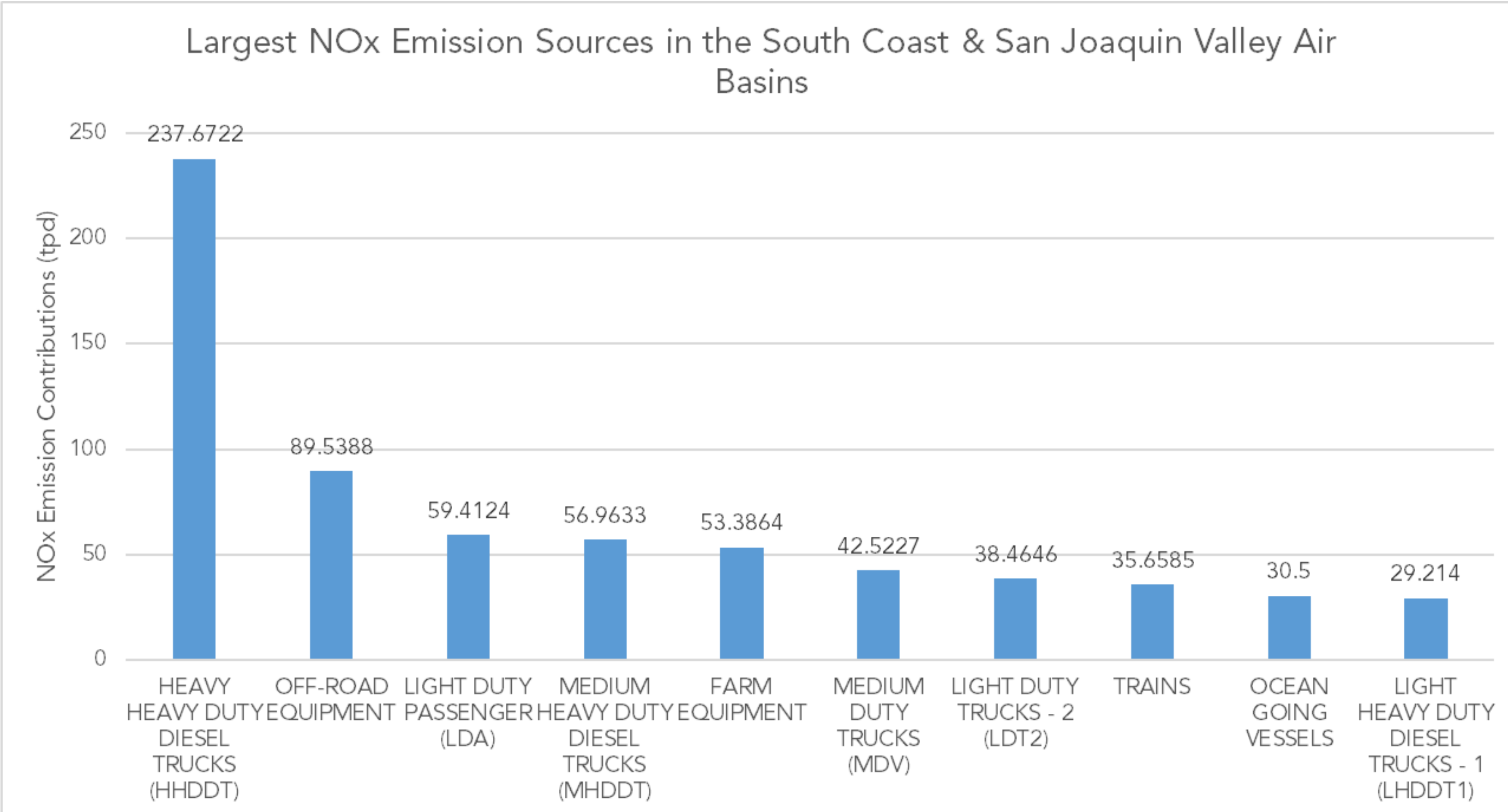
Proposed Project	Annual Per-Vehicle Emission Reductions (tpy)	Project Life (years)	Per-Vehicle Lifetime Emission Reductions (tons)	Score
CC4A	0.0065	3	0.02	1
HVIP	0.0421	15	0.63	1
CORE	0.0631	10	0.63	1

Contribution to Regional Air Quality Improvement

Staff developed a scoring scale based on CARB's emissions inventory for the South Coast and San Joaquin Valley air basins, two of the state's extreme nonattainment regions, and ranked projects based on their corresponding emissions contributions from highest to lowest. Specifically, staff used the NOx emissions inventory in tons per day from the 2016 State Implementation Plan (SIP) emission projection data for the South Coast and San Joaquin Valley air basins.[23] The ranking scale is based on the emissions inventory shown in Figure B-1.

[23] https://www.arb.ca.gov/ei/maps/2017statemap/abmap.htm

Figure B-1: Largest NOx Emission Sources in the South Coast & San Joaquin Valley Air Basins



The top ten NOx emission sources were ranked in tons per day for various vehicle and equipment types, ranging from heavy heavy-duty diesel trucks, at 238 tons per day, to light heavy duty diesel trucks, at 29 tons per day. Because the HHD diesel truck category is the largest emission source by far, the scoring scale for this criterion was established for the range of NOx emissions between the second highest and lowest value. As a result, the bins were rounded and scaled in 25-ton per day increments. Projects corresponding to inventory sources with less than or equal to 25 tons of NOx per day receive one point, while those projects with greater than 100 tons of NOx per day receive five points. Each project's potential contribution to regional air quality improvement was ranked based on the scale below.

5: Category contributes more than 100 tons of NOx per day
4: Category contributes 75 to 99 tons of NOx per day
3: Category contributes 50 to 74 tons of NOx per day
2: Category contributes 25 to 49 tons of NOx per day
1: Category contributes less than 25 tons of NOx per day

Based on the information described above, Table B-21 summarizes the results and the corresponding score for this additional preference criterion.

Table B-21: AB 8 Analysis – Contribution to Regional Air Quality Improvement

Proposed Project	Score
CC4A	1
HVIP	5
CORE	3

<u>Ability to Promote the Use of Clean Alternative Fuels and Vehicle Technologies</u>

Clean alternative fuels are fuels that have lower well-to-wheel emissions compared to conventional fuels, such as electricity, hydrogen, and renewable fuels. Clean vehicle technologies are technologies that emit zero tailpipe emissions, such as battery-electric and fuel cell vehicles, or enabling technologies, such as vehicles that utilize conventional hybrid or plug-in hybrid systems. This qualitative analysis ranked projects by whether or not they used a clean low carbon alternative or renewable fuel or utilized clean vehicle technologies. Staff scored this additional preference criterion on the scale below.

5: Projects that use low carbon alternative fuels <u>and</u> clean vehicle technologies
3: Projects that use low carbon alternative fuels <u>or</u> clean vehicle technologies
1: Projects that do not use low carbon alternative fuels nor clean vehicle technologies

Based on the information described above, Table B-22 summarizes the results and the corresponding score for this additional preference criterion.

Table B-22: AB 8 Analysis – Ability to Promote the Use of Cleaner Alternative Fuels and Vehicle Technologies

Proposed Project	Score
CC4A	5
HVIP	5
CORE	5

<u>Ability to Achieve GHG Reductions</u>

Similar to the methodology established in the first preference criterion for criteria pollutant and toxic air contaminant emission reductions, staff conducted a full well-to-wheel GHG emissions analysis for the vehicles and equipment supported by the proposed projects. Staff determined expected lifetime GHG emission reductions achieved for each vehicle or equipment funded by the proposed projects. The scoring scale for GHG emission reductions is shown below.

5: Greater than 400 metric tons of CO_2e per vehicle
4: 300 to 399 metric tons of CO_2e per vehicle
3: 200 to 299 metric tons of CO_2e per vehicle
2: 100 to 199 metric tons of CO_2e per vehicle
1: Less than 100 metric tons of CO_2e per vehicle

Based on the information described above, Table B-23 summarizes the results and the corresponding score for this additional preference criterion.

Table B-23: AB 8 Analysis – Ability to Achieve GHG Emission Reductions

Proposed Project	Annual Per-Vehicle GHG Emission Reductions (tpy)	Project Life (years)	Per-Vehicle Lifetime GHG Emission Reductions (tons)	Score
CC4A	3.71	3	11.1	1
HVIP	32.5	15	488	5
CORE	61.4	10	614	5

Ability to Support Market Transformation of California's Vehicle or Equipment Fleet to Utilize Low Carbon or Zero-Emission Technologies

This qualitative analysis ranked projects by whether or not technologies with the potential for market transformation are supported by the proposed projects. Staff used CARB's Long-Term Heavy-Duty Investment Strategy from Low Carbon Transportation and Air Quality Improvement Program Investments as a key reference in scoring technologies used for this evaluation. Low NOx engines, battery-electric, and fuel cell electric vehicle technologies, for example, are considered transformative technologies that will help the State meet its air quality goals. Staff scored this preference criterion based on the scale below.

5: Technologies that support market transformation
0: Technologies that do not support market transformation

Based on the information described above, Table B-24 summarizes the results and the corresponding score for this additional preference criterion.

Table B-24: AB 8 Analysis – Ability to Support Market Transformation of California's Vehicle or Equipment Fleet to Utilize Low Carbon or Zero-Emission Technologies

Proposed Project	Score
CC4A	5
HVIP	5
CORE	5

Ability to Leverage Private Capital Investments

Staff is proposing not to include this criterion for FY 2020-21 as staff works on developing methodologies to analyze the private capital investments leveraged by projects. Staff intends to identify information sources and may include this preference criterion in future years.

Total Benefit Index

Staff utilized the benefit-cost/cost-effectiveness scores of the proposed projects and the additional preference criteria in the consideration of the projects to be given funding preference under AB 8. Staff developed the Total Benefit Index (TBI) score that preferentially weights the benefit-cost score (at 75 percent of the total score) with additional preference scores (at 25 percent of the total score). Staff weighted the benefit-cost/cost-effectiveness scores in this manner because AB 8 identified the benefit-cost score as the primary metric to assign funding preference for proposed projects.

Table B-25 summarizes the individual scores and the TBI scores for the AQIP projects currently proposed in the FY 2020-21 Funding Plan.

Table B-25: AB 8 Analysis – Project Scores and Total Benefit Index Score of Proposed Projects

Proposed Project	Additional Preference Criteria					25% of TBI	75% of TBI	Total Benefit Index Score
	Potential Reduction of Criteria or Toxic Air Pollutants	Contribution to Regional Air Quality Improvement	Ability to Promote Use of Clean Fuels and Technologies	Ability to Achieve GHG Emission Reductions	Ability to Support Market Transformation	**Average of Additional Preference Criteria Score**	**Benefit-Cost Score**	
CC4A	1	1	5	1	5	2.4	1	1.35
HVIP	1	5	5	5	5	4.2	1	1.8
CORE	1	3	5	5	5	3.8	1	1.7

Based on the total benefit index score, as well as its high demand, staff recommends that the $25 million of AQIP funds goes to support HVIP. While staff recognizes the need to fund all these projects, providing the funding to HVIP would result in the greatest benefits.