Appendix A

Emission Reductions: Quantification Methodology

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EMISSION REDUCTIONS: QUANTIFICATION

Overview

In the Governor's proposed budget for the 2016-17 fiscal year (FY), ARB was appropriated $28.6 million for Air Quality Improvement Program (AQIP) projects and $500 million in Cap-and-Trade auction proceeds for Low Carbon Transportation and Fuels investments. This appendix conservatively estimates the emission reductions of the project categories found in the Funding Plan and provides additional details on the methodology developed and assumptions used. This analysis was guided by AB 8 (Perea, Chapter 401, Statutes of 2013) and published Greenhouse Gas Reduction Fund (GGRF) quantification methodologies.[1] Because criteria pollutant emission reductions are geographically localized, values reported herein are estimated at the tailpipe. Greenhouse gas (GHG) emission reductions were tabulated on a well-to-wheel (WTW) basis, as GHGs are a statewide pollutant.

ARB anticipates updating and revising the analysis in each subsequent Funding Plan as new data become available and methodologies are refined. 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. For this Funding Plan, the methodology has been updated, as have the emission factors, assumptions, and projects. This appendix serves as the analysis required under the AB 118 Air Quality Guidelines for the AQIP projects.

Table A-1 summarizes the funding allocations for the projects proposed in the Funding Plan and the potential emissions benefits over the project life.

[1] Cap-and-Trade auction proceeds quantification materials available at: http://www.arb.ca.gov/cc/capandtrade/auctionproceeds/quantification.htm

Table A-1: Summary of Proposed Projects in the FY 2016-17 Funding Plan and Total Potential Emission Reductions

Phase	Project	Proposed FY 2016-17 Allocation (millions)	# of Vehicles/ Equipment or Gallons of Fuel Funded	Total Potential Emission Reductions	
				Weighted Tailpipe Criteria Emissions (tons)	Well-to-Wheel GHG Emissions (metric tons CO_2e)
Demos	Advanced Technology Demonstrations	$59	90	TBD*	13,690
Commercialization	Zero-Emission Freight Pilot	$5	60	TBD*	48,538
	Zero-Emission Truck Pilot	$18	66	TBD*	24,428
	Zero-Emission Transit Bus Pilot	$42	43	TBD*	38,705
	Rural School Bus Pilot	$10	45	TBD*	10,127
	CVRP	$230	98,000	4,307	3,762,249
	HVIP	$18	500	142	64,164
	Low NOx Engines[2]	$23	1,200	220	94,304
	Very Low Carbon Fuels Incentive	$40	67,000,000	TBD*	424,020
Transition	Truck Loan Assistance[3]	$22	3,900	3,290	N/A
	Agricultural Equipment Trade-Up Pilot[3]	$3	50	189	N/A
Pilot Projects to Benefit DACs	EFMP Plus-up	$30	4,900	104	25,419
	Car Sharing Pilot Project	$8	550	TBD*	2,707
	Agricultural Worker Vanpools	$3	60	TBD*	1,907
	Public Fleets in DACs	$3	400	15	12,782
	Light-Duty Financing Assistance	$6	550	TBD*	3,688

* For new projects, quantification of the criteria pollutant benefits will be determined during the solicitation process.

[2] The GHG benefits for low NOx engines are due to the project's renewable fuel requirement.
[3] GHG emissions are not quantified for the Truck Loan Assistance and Agricultural Equipment Trade-Up Pilot projects as explained later in the appendix.

Table A-2 summarizes the benefit-cost score for the projects funded under AQIP, consistent with AB 8 requirements.

Table A-2: Summary of AB 8 Scoring Analysis for AQIP Funded Projects

Project	Proposed FY16-17 Allocation (millions)	Cost Recovery Factor (CRF)	Weighted Criteria Emission Reductions (tons per year or tpy)	Per Vehicle Incentive Levels ($)	Cost-Effectiveness ($/ton)	Benefit-Cost Score (lbs/$)
Truck Loan Assistance	$22	0.35	0.28	$10,000	$12,340	0.16
Agricultural Equipment Trade-Up Pilot	$3	0.21	0.76	$50,000	$14,013	0.14

AB 8 Background

The analysis and methodology in this appendix describes the implementation of the provisions that require ARB to assign preference to projects with a higher benefit-cost score. This analysis is fully executed for the two projects that will be funded through AQIP: the Agricultural Equipment Trade-Up Pilot Project and the Truck Loan Assistance Program. 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.[4]
- "Benefit-cost score" means the reasonably expected or potential criteria pollutant emission reductions achieved per dollar awarded by the Board for the project.[5]
- The state board also may give additional preference based on the following criteria, as applicable, in funding awards to projects:[6]

    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.

[4] Health & Safety Code Section 44274(b)
[5] Health & Safety Code Section 44270.3(e)(1)
[6] Health & Safety Code Section 44274(b)

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 ARB to annually evaluate potential project categories to assign preference for AQIP funding, based upon the specific criteria identified above. Staff's analysis and evaluation methodology was applied to the proposed project types funded with AQIP, as identified in the FY 2016-17 Funding Plan, to determine project-specific benefit-cost scores.

Methodology

Conservative estimates for criteria pollutant and GHG emission reductions were developed using guidance provided in AB 8. Because criteria pollutant emission reductions are geographically localized, values reported herein are estimated at the tailpipe. Greenhouse gas emission reductions were tabulated on a well-to-wheel basis, as GHGs are a statewide pollutant. This appendix provides additional information regarding the emission factors used in the quantification of emission benefits. For applicable projects, cost evaluation, analysis to support the additional preference criteria, and scoring methodology is also included. This appendix provides information on the following:

- Emissions Benefit Analysis for all projects;
- Cost Analysis for all projects;
- Benefit-Cost Score Analysis for AQIP-funded projects;
- Additional Preference Criteria for AQIP-funded projects;
- Total Benefit Index for AQIP-funded projects; and
- Lifetime Emission Reductions Analysis for all projects.

Emissions Benefit Analysis

Emission Factors

To support the analysis of emission reductions from the proposed projects, staff developed a set of emission factors for the six different vehicle classes shown below. The emission factors and assumptions used in the analysis were derived from a number of sources such as ARB's California-modified Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (CA-GREET 2.0) model,[7] ARB's Emission Factor (EMFAC2014) Model,[8] information from ARB regulation staff reports, publically available technical reports, and staff assumptions.

[7] http://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet.htm
[8] http://www.arb.ca.gov/emfac/2014/

Based on the proposed project types in the Funding Plan, staff developed emission factors for six general vehicle classes:

- Light-duty vehicles (LDV);
- Light heavy-duty vehicles (LHD);
- Medium heavy-duty vehicles (MHD);
- Heavy heavy-duty vehicles (HHD);
- Urban buses; and
- School buses.

GHG Emission Factors

Fuel economy is an important component of the emissions analysis, as the value determines the emissions generated based on the production of each unit of fuel for the miles traveled. Fuel economy values were derived from EMFAC2014. The fuel economy was paired with upstream emission data derived from the LCFS to calculate the WTW GHG emissions for each project type. This was done so that the well-to-tank emissions of the fuel were representative of the fuel used, paired with the specific technology. Table A-3 summarizes the baseline fuel economy estimates used in the analysis of conventional vehicles.

Table A-3: Fuel Economy Values of Baseline Conventional Vehicles

Vehicle Class	Fuel Type	Fuel Economy (mpg)				
		1995	1998	2008	2011	2016
LDV	Gasoline	23.1	-	-	-	29.9
LHD	Gasoline	-	-	-	-	10.8
MHD	Diesel	-	-	-	-	8.6
HHD	Diesel	-	5.1	5.4	5.5	6.3
Urban Buses	Diesel	-	-	-	-	5.2
School Buses	Diesel	-	-	-	-	7.4

Staff developed upstream emission factors that were based on the mix of feedstock used in the production of the various fuels. Staff assumed the following upstream pathways for the fuels analyzed:

- Gasoline: California reformulated gasoline (CaRFG) used to calculate baseline and conventional hybrid emission factors;
- Diesel: Ultra-low-sulfur diesel (ULSD);
- Compressed Natural Gas (CNG): CNG formed from natural gas or flare gas;
- Electricity: Current California average mix used to calculate battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV) emission factors;
- Hydrogen: Mix of gaseous hydrogen formed on-site at the refueling station from North American natural gas and 33 percent renewable hydrogen from biomass, such as landfill gas, used to calculate fuel cell vehicle (FCV) emission factors;
- Renewable Diesel (RD): Tallow-based renewable diesel; and

- Renewable Natural Gas (RNG): Landfill gas to CNG (off-site refueling).

It should be noted that as more renewables are introduced into the transportation fuel pool, additional 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 Emission Factors

For the determination of tailpipe criteria pollutant emission factors, staff utilized ARB's EMFAC2014 model to calculate the tailpipe emissions and emissions associated with the usage of the supported vehicles or equipment such as PM emissions from brake and tire wear, when applicable. 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 hybrid MHDs are based on a certified vertically integrated hybrid vehicle. Moreover, improved fuel economy from the use of a hybrid system[9] provides improvements in the emission factors as less fuel is used and the upstream (well-to-tank) GHG emissions are reduced. Emission factors were developed for advanced technology vehicles supported by the proposed projects when appropriate, along with emission factors for new conventional vehicles.

Table A-4 through Table A-9 provide an overview of the emission factors generated for each vehicle category.

Table A-4: Emission Factors for Light-Duty Vehicles (LDV)

(g/mi)	2016 Gasoline	PHEV	BEV
HC	0.005	0.003	0
NOx	0.032	0.019	0
PM	0.020	0.011	0.010
GHG (gCO_2e/mi)	382	243	120

Note: Staff assumed PHEV operate in all-electric mode 40 percent of the time with additional fuel economy improvements provided by the use of the hybrid drivetrain.[10]

Table A-5: Emission Factors for Light Heavy-Duty (LHD) Vehicles

(gCO_2e/mi)	2016 Gasoline	Conventional Hybrid
GHG	1,060	848

[9] 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

[10] Consistent with assumptions used in 2012 Proposed Amendments to the California Zero-Emission Vehicle Program Regulations Staff Report: Initial Statement of Reasons. http://www.arb.ca.gov/regact/2012/zev2012/zevisor.pdf

Table A-6: Emission Factors for Medium Heavy-Duty (MHD) Vehicles

(g/mi)	2016 Diesel	Conventional Hybrid	BEV
HC	0.02	0.02	0
NOx	0.49	0.39	0
PM	0.06	0.03	0.03
GHG (gCO_2e/mi)	1,596	1,277	609

Table A-7: Emission Factors for Heavy Heavy-Duty (HHD) Vehicles

(gCO_2e/mi)	2016 Diesel	BEV	FCV
GHG	2,181	833	994

Table A-8: Emission Factors for Urban Buses

(g/mi)	2016 Diesel	CNG	BEV	FCV
HC	0.02	1.63	0	0
NOx	1.82	0.47	0	0
PM	0.37	0.36	0.18	0.18
GHG (gCO_2e/mi)	2,640	2,254	648	1,203

Note: For baseline urban bus emission factors, staff assumed an average between diesel and CNG baseline urban buses, as the current California fleet utilizes a mix of the two fuel types.

Table A-9: Emission Factors for School Buses

(gCO_2e/mi)	2016 Diesel	RD	BEV
GHG	1,859	761	456

Project-Specific Emission Factors

In some cases, staff determined project-specific emission factors. These projects include:

- Truck Loan Assistance Program – emission factors updated to reflect program-specific data;
- Low NOx Engine Incentives – emission factors updated to reflect CNG/RNG fuels and a 2016 CNG MHD vehicle baseline;
- Enhanced Fleet Modernization Program (EFMP) Plus-up – emission factors updated to reflect program-specific data;
- Agricultural Equipment Trade-Up Pilot – emission factors updated to reflect the Agricultural Equipment Inventory;
- Light-Duty Financing Assistance – emission factors updated to reflect EFMP Plus-up program-specific data; and
- Very Low Carbon Fuels Incentive – WTW emission factors based on LCFS.

Truck Loan Assistance Program:

The Truck Loan Assistance Program aids small business truckers affected by ARB's In-Use Truck and Bus Regulation by providing financing assistance for fleet owners to upgrade their fleets with newer trucks or with diesel exhaust retrofits. Emission factors were developed specifically for the Truck Loan Assistance Program because program data indicates alternative model years should be used for the analysis. Based on data from program inception through March 31, 2016, on average, funds were directed toward the replacement of 1998 engine model year (MY) diesel trucks with a mix of HHD trucks equipped with engine model years 2008 and 2011.

While analyzing annual purchase trends, staff has seen an increasing number of trucks with MY 2010 or newer engines purchased through the Truck Loan Assistance Program. In 2016, with more than 1,000 loans financed so far, project data indicate that 70 percent of the replacements were trucks with MY 2010 or newer engines, and MY 2007-2009 engines trucks made up the remaining 30 percent. Staff used this engine model year information and a weighted average of the emission factors for the analysis.

Finally, PM reductions are not included in the benefit-cost score as PM reductions are required by the In-Use Truck and Bus Regulation. Table A-10 below summarizes the tailpipe emission factors for the Truck Loan Assistance Program to be used in the benefit-cost score analysis.

Table A-10: Emission Factors for Truck Loan Assistance Program*

(g/mi)	1998 Diesel	2008 Diesel	2011 Diesel
HC	0.61	0.24	0.09
NOx	18.54	10.20	3.10

*Population-weighted average of EMFAC2014 T7 categories, excluding out-of-state vehicles

Low NOx Engine Incentives:

For FY 2016-17, the Funding Plan proposes incentivizing the deployment of certified low NOx engines. The project will support deployment of engines that meet optional low NOx standards, which provide manufacturers the ability to certify engines to NOx emission levels that are 50 percent, 75 percent, or 90 percent lower than today's mandatory heavy-duty engine emission standards. In September 2015, ARB certified the first low NOx 8.9-liter, medium heavy-duty engine to the lowest standard of 0.02 g/bhp-hr. Staff proposes that this project provide funding for both new vehicle purchases and engine repowers with engines certified to any of the optional low NOx standards.

Since the only currently available low NOx engines are natural gas engines and because we are proposing to fund only the incremental cost of going from a conventional CNG to a low NOx CNG engine, staff utilized a 2016 medium heavy-duty

CNG vehicle and the associated fuel economy value as the baseline for this analysis. Staff assumed the medium heavy-duty vehicle class because it is one of the intended service classes for this engine type. When more data is available on how this engine is being deployed, staff will update this analysis.

In order to maximize the GHG emission benefits of low NOx engines, staff proposes requiring the use of 100 percent renewable fuels for the first 3 years. Since low NOx engines are only available for natural gas at this time, staff developed emission factors for RNG. For GHG emission factors, staff derived data from CA-GREET 2.0 and used CI values from LCFS to determine the upstream GHG emissions generated for RNG from landfill gas and emissions from the associated vehicle usage.

Additionally, criteria pollutant emission factors were developed using the optional low NOx engine emission standards and tailpipe emissions data of medium heavy-duty diesel vehicles in EMFAC2014 as the baseline. Considering the only optionally certified low NOx engine meets the standard that is 90 percent lower than the diesel baseline, staff assumed a 90 percent tailpipe NOx reduction for RNG. Table A-11 summarizes the emission factors for the baseline, conventional CNG vehicle and the low NOx replacement engine fueled with RNG to be used in the analysis.

Table A-11: Emission Factors for CNG Trucks

(g/mi)	2016 CNG Baseline	Low NOx CNG Engine Fueled with RNG
HC	0.02	0.02
NOx	0.49	0.05
PM	0.06	0.06
GHG (gCO_2e/mi)	1,363	315

EFMP Plus-up:

EFMP Plus-up, also known as the Enhanced Fleet Modernization Program (EFMP) Plus-up Pilot Project, is a pilot project that provides additional incentives for lower-income consumers to retire old vehicles and replace them with used or new hybrid, plug-in hybrid, or zero-emission vehicles. According to the EFMP staff report,[11] the average MY of a vehicle replaced through EFMP is 1995. Staff calculated the average fuel economy and annual VMT of a 1995 MY vehicle from EMFAC2014 for the 2016 calendar year to use as the baseline.

Based on updated project data, staff found that funding in 2015 and 2016 has been split between approximately 20 percent BEVs, 25 percent PHEVs, and 55 percent conventional hybrids, so the emission factors of the new technologies were weighted in the analysis. EFMP Plus-up emission factors based on the information above were derived from LCFS, CA-GREET 2.0, and EMFAC2014 and summarized in Table A-12.

[11] http://www.arb.ca.gov/regact/2014/carscrap14/efmp14isor.pdf

Table A-12: Emission Factors for EFMP Plus-up

(g/mi)	1995 Gasoline	Conventional Hybrid	PHEV	BEV
HC	0.086	0.005	0.003	0
NOx	0.454	0.032	0.019	0
PM	0.028	0.012	0.011	0.010
GHG (gCO_2e/mi)	495	326	243	120

Agricultural Equipment Trade-Up Pilot:

The purpose of the Agricultural Equipment Trade-Up Pilot project in the San Joaquin Valley is to provide smaller growing operations' vehicle owners who cannot use current incentive options with a mechanism to "trade-up" an older, high-emitting tractor to a pre-owned, cleaner tractor provided by another growing operation's vehicle owner who is seeking to replace their tractor with the cleanest technology available. This pilot would provide an incentive for those grower operation's vehicle owners to upgrade their equipment to the cleanest available technology.

Due to this pilot project's focus on mobile agricultural equipment and its emission benefits from two tractors per trade, there are slight variances in the analysis. First, the tractors being traded are all diesel-fueled (no alternative fuels). The diesel technology in new tractors reduce criteria pollutant emissions more efficiently, with Tier 4 final engines being the cleanest available and Tier 0 engines being uncontrolled. Since the fuel type is the same for each tractor involved, and staff found the overall fuel consumption remained approximately the same according to ARB's 2015 Agricultural Equipment Inventory,[12] upstream emissions were not quantified, and only the downstream criteria pollutant emission factors are shown in Table A-13 for each engine tier within the assumed horsepower range.

According to ARB's Agricultural Equipment Inventory, the average tractor in the San Joaquin Valley is between 76 and 100 horsepower; therefore, staff used emission factors for this horsepower range in the analysis. Since the diesel emission control technologies only reduce criteria pollutants, GHG emissions are not included or quantified. In addition, emission factors for agricultural equipment are measured in grams per hour, rather than the grams per mile associated with on-road vehicle emissions. Other adjustments to the analysis associated with this project are addressed throughout the appendix.

[12] http://www.arb.ca.gov/ag/agtractor/agtractor.htm

Table A-13: Emission Factors for Agricultural Equipment Trade-Up Pilot

(g/hr)	Tier 0	Tier 2	Tier 4 Final
HC	69.9	13.0	1.2
NOx	503.6	233.2	4.0
PM	37.6	14.6	0.4

Light-Duty Financing Assistance:

The purpose of the Light-Duty Financing Assistance project is to assist lower-income consumers in purchasing clean vehicles by improving access to more affordable financing options. This project includes mechanisms such as loan loss guarantees, interest rate buy-downs, and vehicle cost buy-downs. This project was introduced in the FY 2014-15 Funding Plan and launched to the public in early 2016. Due to the recent project launch date, staff does not have much data on this project. However, since this project is designed to assist the same consumer base as EFMP Plus-up, staff used EFMP data to estimate potential emission reductions as explained further below.

According to EFMP data, the average replacement vehicle is a 2013 model year. Since the proposed Light-Duty Financing Assistance project assists with the purchase of vehicles up to 8 years old, a 2013 model year, conventional gas vehicle is used as the baseline. Staff anticipates that lower-income consumers may pair this program with EFMP Plus-up, and thus, the technology splits seen in EFMP Plus-up were assumed to be similar to the Financing Assistance project as well (20 percent BEVs, 25 percent PHEVs, and 55 percent conventional hybrids). Staff used the emission factors corresponding to this technology split for new vehicles. It should also be noted that because this program may be used in conjunction with EFMP Plus-up, CVRP, and other programs, there is the potential for double counting emission reductions achieved through these programs.

The emission factors for the Light-Duty Financing Assistance project were calculated based on data derived from CA-GREET 2.0 and EMFAC2014 and are summarized in Table A-14 below.

Table A-14: Emission Factors for Light-Duty Financing Assistance

(gCO_2e/mi)	2013 Gasoline	Conventional Hybrid	PHEV	BEV
GHG	495	326	243	120

Very Low Carbon Fuels Incentive:

The purpose of the Very Low Carbon Fuels Incentive Project is to increase the volume of very low carbon transportation fuels produced and used in California and to accelerate the reduction in the carbon intensity of these fuels. This project was introduced for the first time in the Governor's proposed 2016-17 Budget as a new project category. Since this program incentivizes fuels rather than vehicles or

equipment, this analysis uses the LCFS 2010 base year carbon intensity values for fuels used as diesel and gasoline substitutes.

To be conservative for the replacement fuels, staff used 40 percent of the 2010 base year LCFS carbon intensity values, as these will be the maximum allowable carbon intensity values of fuels eligible for incentives under this program. For the analysis, staff converted the CI values from LCFS into gasoline gallon equivalent (gge) values, which are the standard units for this project. For this analysis, criteria pollutant emission factors are not calculated as the production volumes and types of fuels incentivized are still unknown.

Table A-15: Emission Factors for Very Low Carbon Fuels Incentive

(gCO_2e/gge)	Diesel Baseline	Gasoline Baseline	Gasoline Replacement Fuels	Diesel Replacement Fuels
GHG	11,816	11,406	4,562	5,487

Supported Vehicles and Fuels

With the emission factors generated for each of the vehicle types or fuel replacements, staff then analyzed the GHG emission benefits for each of the proposed projects and the criteria pollutant emission benefits, when applicable. Evaluations were performed by comparing the advanced clean vehicles supported by projects proposed in the Funding Plan to a new, conventional baseline vehicle, unless project data indicated that another baseline vehicle should be used. For the evaluation of the Very Low Carbon Fuels Incentive project, staff compared the LCFS 2010 base year CI value to the maximum CI value of fuels eligible under the program. Staff performed analyses on the following projects with the corresponding emission factors:

- CVRP (Emission Factors: LDV);
- Light-Duty Pilot Projects to Benefit Disadvantaged Communities (DACs):
    - EFMP Plus-up Pilot Project (Table A-12);
    - Car Sharing Pilot Project (Emission Factors: LDV);
    - Agricultural Worker Vanpools (Emission Factors: LHD);
    - Public Fleets in Disadvantaged Communities (Emission Factors: LDV);
    - Light-Duty Financing Assistance (Emission Factors: Table A-14);
- Advanced Technology Demonstration Projects (Emission Factors: HHD);
- Zero-Emission Freight Pilot (Emission Factors: HHD);
- Zero-Emission Truck Pilot (Emission Factors: MHD);
- Zero-Emission Bus Pilot (Emission Factors: Urban Bus);
- Rural School Bus Pilot (Emission Factors: School Bus);
- HVIP (Emission Factors: MHD and Urban Bus);
- Low NOx Engine Incentives (Emission Factors: Table A-11)
- Truck Loan Assistance Program (Emission Factors: Table A-10);

- Agricultural Equipment Trade-Up Pilot (Emission Factors: Table A-13); and
- Very Low Carbon Fuels Incentive (Emission Factors: Table A-15).

Advanced Technology Demonstration Projects proposed for FY 2016-17 consist of various categories including on-road trucks, off-road freight equipment, and non-freight off-road equipment. The Zero-Emission Freight Pilot consists of various eligible zero-emission vehicle and equipment types. Details regarding the vehicles and equipment supported by these demonstration and pilot projects will not be known until the projects are launched, therefore staff selected representative technologies to determine emission factors: zero-emission short and regional haul trucks, a project proposed in the Funding Plan, for the Advanced Technology Demonstration Projects and zero-emission yard trucks for the Zero-Emission Freight Pilot analyses.

Similarly, light-duty pilot projects to benefit DACs were introduced in FY 2014-15 and while there is a data collection component to the projects, the majority of the projects have not yet launched, and therefore, the current information on the projects is limited. To evaluate light-duty pilot projects to benefit DACs, staff refined the previous years' analyses, which included increased incentives for public fleets, car sharing and mobility options, and EFMP Plus-up. For the projects that have not yet launched, staff used representative vehicles and technologies to quantify agricultural worker vanpools and light-duty financing assistance for lower-income consumers. For the agricultural worker vanpools project, staff used the EMFAC2014 category for light heavy-duty trucks with 8,501 to 10,000 pounds GVWR to represent passenger vans, and for the Light-Duty Financing Assistance project, staff used EFMP Plus-up data.

Using the emission factors identified above with project data and assumptions, staff determined the vehicles or equipment that may be supported by the projects to provide emission reductions for each of the projects in FY 2016-17. Table A-16 summarizes the supported technologies and vehicles that were used in the analysis to calculate the emission benefits based on currently available advanced technologies.

Table A-16: Supported Technology Types by Proposed Project

Phase	Proposed Project	Representative Supported Technology Types	Comments
Demos	Advanced Technology Demonstrations	Fuel cell and battery-electric short and regional haul trucks (HHD)	Eligible technologies
Commercialization	Zero-Emission Freight Pilot	Electric yard trucks (HHD)	Eligible technology
	Zero-Emission Truck Pilot	Battery-electric medium heavy-duty trucks	Assumption based on project data
	Zero-Emission Transit Bus Pilot	Fuel cell and battery-electric urban buses	Eligible technologies
	Rural School Bus Pilot	Battery-electric school buses and school buses utilizing renewable fuels	50/50 split of the two technologies assumed, staff assumed renewable diesel fuel for the evaluation
	CVRP	Plug-in hybrid and battery-electric passenger cars	40% PHEVs and 60% BEVs, based on CVRP rebate data since program inception
	HVIP	Hybrid and battery-electric medium heavy-duty trucks	95% of total HVIP funding with 85% hybrid and 15% battery electric split, based on HVIP data from 2015-16
		Battery-electric urban transit buses	5% of total HVIP funding; assumption based on HVIP data from 2015-16
	Low NOx Engines	Low NOx engines utilizing RNG	90% reduction in NOx from the medium heavy-duty engine standard, fueled with RNG 100% of the time
	Very Low Carbon Fuels Incentive	Fuels with a CI value of 40% or less, in comparison to the 2010 base year CI values from LCFS	Eligible fuel pathways under LCFS
Transition	Truck Loan Assistance	Replacement of a 1998 MY with a 2008 MY or 2011 MY (HHD) truck or trailer	Assumption based on project data
	Agricultural Equipment Trade-Up	Advanced diesel engines with emission control technologies	Tier 4 tractors replacing Tier 2 tractors, subsequently replacing Tier 0
Pilot Projects to Benefit DACs	EFMP Plus-up	Conventional (gasoline) hybrid, plug-in hybrid, and battery-electric passenger vehicles	20% BEVs, 25% PHEVs, and 55% conventional hybrids, based on project data
	Car Sharing Pilot Project	Plug-in hybrid and battery-electric passenger vehicles	50/50 split of the two technologies assumed
	Agricultural Worker Vanpools	Light heavy-duty van conversion to conventional hybrid system	Eligible technology
	Public Fleets in DACs	Plug-in hybrid and battery-electric passenger vehicles	50/50 split of the two technologies assumed
	Light-Duty Financing Assistance	Conventional (gasoline) hybrid, plug-in hybrid, and battery-electric passenger vehicles	Staff assumption - same technology split as EFMP Plus-up

Staff generated vehicle usage assumptions (annual vehicle miles traveled or VMT) through literature review for each of the vehicle types evaluated, data from EMFAC2014, and actual usage data from the projects, when available. Table A-17 summarizes the annual usage assumptions used for emissions benefit analysis.

Table A-17: Annual Usage Assumptions

Phase	Proposed Project	Annual Usage Assumptions (mi/year or hrs/year)	Details
Demos	Advanced Technology Freight Demonstrations	40,000	According to California Hybrid, Efficient and Advanced Truck Research Center's (CalHEAT) report,[13] short haul/regional trucks operate 55,000 miles a year; staff used conservative estimates for the use of advanced technologies and will update the annual usage as project data becomes available
Commercialization	Zero-Emission Freight Pilot	40,000	Staff assumption based on 51,000 miles per year for 2016 model year, diesel HHD vehicles in EMFAC2014 - staff used conservative estimates for the use of advanced technologies and will update the annual usage as project data becomes available
	Zero-Emission Truck Pilot	25,000	Staff assumption based on annual VMT of 2016 model year, diesel MHD vehicles in EMFAC2014
	Zero-Emission Bus Pilot	35,000	National Renewable Energy Laboratory's (NREL) Technical Report, "NREL/TP-7A2-47919"[14]
	Rural School Bus Pilot	13,500	Based on annual VMT of diesel school buses in EMFAC2014 (average of all model years)
	CVRP	EV: 11,059	Based on 30.3 miles per day[15]
		PHEV: 14,855	Based on 40.7 miles per day[16]
		Hybrid: 14,855	Staff assumption - same as PHEVs
	HVIP	EV: 12,000 Hybrid: 22,000	Climate Change Scoping Plan, Measure Documentation Supplement[17], Measure T-7
	Low NO_x Engines	25,000	Staff assumption based on annual VMT of 2016 model year, diesel MHD vehicles in EMFAC2014
Transition	Truck Loan Assistance	18,500	Based on annual VMT of 1998 model year, T7 diesel trucks, excluding out-of-state vehicles, from EMFAC2014
	Agricultural Equipment Trade-Up	Large Farm: 660 Small Farm: 430	Based on average annual usage hours from ARB's Agricultural Equipment Inventory[18]

[13] http://www.calstart.org/Libraries/CalHEAT_2013_Documents_Presentations/CalHEAT_Roadmap_Final_Draft_Publication_Rev_6.sflb.ashx
[14] http://www.afdc.energy.gov/pdfs/47919.pdf
[15] 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/)
[16] 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] http://www.arb.ca.gov/cc/scopingplan/document/measure_documentation.pdf
[18] http://www.arb.ca.gov/msei/msei.htm

Phase	Proposed Project	Annual Usage Assumptions (mi/year or hrs/year)	Details
Pilot Projects to Benefit DACs	EFMP Plus-up	7,500	Based on the average VMT of a 1995 MY light-duty passenger vehicle operating in 2016 from EMFAC2014
	Car Sharing Pilot Project	8,200	Based on the average miles driven for vehicles shared by U.S. carsharing members[19]
	Agricultural Worker Vanpools	25,000	Based on the annual VMT of 2016 model year, gasoline-fueled, light heavy-duty vehicles with GVWR of 8,501-10,000 lbs in EMFAC2014
	Public Fleets in DACs	10,647	California Department of General Services 2010 Fleet Report[20]
	Light-Duty Financing Assistance	EV: 11,059 PHEV: 14,855 Hybrid: 14,855	Since Light-Duty Financing Assistance will be used to purchase a new or lightly used vehicle, staff assumed the usage would be the same as CVRP

Annual Emission Reductions

Based on the emission factors (EF) and additional information provided above, the GHG and criteria pollutant emission reductions (NOx, HC, and PM2.5) for supported vehicle types were calculated by multiplying the assumed annual mileage by the difference between the conventional and supported vehicle emissions for each technology type. According to the technology type(s) and ratios shown in Table A-16, GHG emission benefits for each project and in some cases, weighted criteria pollutant emission benefits were calculated for the assumptions. Annual GHG and criteria emissions benefit analyses were performed on a per vehicle basis using the following formula:

$$Emissions\ Reductions = Annual\ VMT\ x$$
$$(EF\ for\ new\ conventional\ vehicle - EF\ for\ advanced\ technology\ vehicle)$$

The above formula is the basis for the following formula, which calculates the annual total criteria pollutant emission reductions for the Agricultural Equipment Trade-Up Pilot. Annual hours of usage per tractor was used in lieu of annual VMT. In addition, reductions from the scenarios of both growing operations' fleets involved were combined, as shown below.

[19] Martin, E., Shaheen, S., and Lidicker, J. "Impact of Carsharing on Household Vehicle Holdings," *Transportation Research Record: Journal of the Transportation Research Board,No. 2143,* Transportation Research Board of the National Academies, Washington, D.C., 2010, pp. 150–158. DOI: 10.3141/2143-19. (http://sfpark.org/wp-content/uploads/carshare/Impact_of_Carsharing_on_Household_Vehicle_Holdings.pdf)

[20] DGS, "Final Report on the Execution of Executive Order S-14-09: Vehicle and Home Storage Permit Reduction", 2010. (http://www.documents.dgs.ca.gov/ofa/FleetReduction/FleetReduction-FinalReport-July2010.pdf)

$$
\begin{aligned}
&Emission\ Reductions\ for\ Agricultural\ Equipment\ Trade - Up \\
&\quad = Annual\ usage\ hours\ at\ large\ farm\ x\ (EF\ for\ Tier\ 2\ tractor \\
&\quad - EF\ for\ Tier\ 4\ Final\ tractor) \\
&\quad + Annual\ usage\ hours\ at\ small\ farm\ x\ (EF\ for\ Tier\ 0\ tractor \\
&\quad - EF\ for\ Tier\ 2\ tractor)
\end{aligned}
$$

Unlike the other projects, the Very Low Carbon Fuels Incentive project is analyzed in terms of gallons of fuel produced in a year, as shown in the following formula:

$$
\begin{aligned}
&Emission\ Reductions\ for\ Very\ Low\ Carbon\ Fuels \\
&= (EF\ for\ LCFS\ baseline\ fuel - EF\ for\ very\ low\ carbon\ substiute\ fuel) \\
&\quad x\ volume\ of\ fuel\ produced\ (in\ gge)
\end{aligned}
$$

As discussed in previous Funding Plans,[21] staff based the analysis of PM emissions on PM2.5 instead of PM10 due to the difference in adverse health impacts associated with PM emissions of different sizes. In order to provide direct comparisons between the projects by comparing similar criteria pollutant emissions, PM2.5 was selected as the corresponding PM emissions component. Moreover, due to the toxicity of PM2.5, staff proposes to assign a greater weight for PM2.5 by weighing it by 20 times, consistent with the methodology outlined in the Carl Moyer Memorial Air Quality Standards Attainment Program's 2011 Guidelines, Appendix C.[22] For the analysis of PM, staff also included tire and brake wear associated with the corresponding vehicle classes and applied a 50 percent reduction[23] for brake wear emissions for vehicles with regenerative braking capability.

Table A-18 on the following page summarizes the potential annual GHG emission benefits from the vehicles and equipment supported by each project, and Table A-19 summarizes the potential GHG emission benefits from the fuels supported by the Very Low Carbon Fuels Incentive project.

[21] http://www.arb.ca.gov/msprog/aqip/fundplan/fundplan.htm
[22] http://www.arb.ca.gov/msprog/moyer/guidelines/2011gl/2011cmp_appc_20151218.pdf
[23] NREL, BAE/Orion Hybrid Electric Buses at New York City Transit, http://www.afdc.energy.gov/pdfs/42217.pdf, March 2008

Table A-18: Potential Per Vehicle Annual GHG Emission Benefits

Phase	Proposed Project	Representative Supported Technologies	Per Vehicle Annual Emission Reductions (metric tons CO_2e/yr)	
			Per Technology Type	Weighted Average[24]
Demos	Advanced Technology Demonstrations	Battery-Electric Short/Regional Haul Trucks	53.93	50.70
		Fuel Cell Short/Regional Haul Trucks	47.48	
Commercialization	Zero-Emission Freight Pilot	Battery-Electric Yard Trucks	53.93	53.93
	Zero-Emission Truck Pilot	Battery-Electric MHD Trucks	24.67	24.67
	Zero-Emission Bus Pilot	Battery-Electric Urban Buses	69.73	60.01
		Fuel Cell Urban Buses	50.29	
	Rural School Bus Pilot	Battery-Electric School Buses	18.93	16.88
		Renewable Diesel School Buses	14.82	
	CVRP[25]	Battery-Electric LDVs	2.90	2.56
		Plug-In Hybrid LDVs	2.05	
	HVIP[26]	Hybrid MHD Trucks	7.02	8.56
		Battery-Electric MHD Trucks	11.84	
		Battery-Electric Urban Buses	23.91	
	Low NOx Engines	Replacement of CNG with MHD low NOx engines fueled with RNG	26.20	26.20
Pilot Projects to Benefit DACs	EFMP Plus-up	Hybrid LDVs	1.27	1.73
		Plug-In Hybrid LDVs	1.88	
		Battery-Electric LDVs	2.81	
	Car Sharing	Plug-In Hybrid LDVs	1.13	1.64
		Battery-Electric LDVs	2.15	
	Agricultural Worker Vanpools	Hybrid LHD Vans	5.30	5.30
	Public Fleets in DACs	Plug-In Hybrid LDVs	1.47	2.13
		Battery-Electric LDVs	2.79	
	Light-Duty Financing Assistance	Hybrid LDVs	1.55	2.24
		Plug-In Hybrid LDVs	2.78	
		Battery-Electric LDVs	3.43	

[24] Average is weighted by supported representative technology types as listed in Table A-16.
[25] While CVRP funds fuel cell vehicles, staff found that fuel cell vehicles account for less than 1 percent of CVRP rebates; therefore, when determining the potential emission reductions, staff used battery-electric and plug-in hybrid vehicles for the analysis.
[26] Since there are no hybrid urban buses available on the market today, staff used a mix of hybrid and battery-electric trucks and battery-electric urban buses for the analysis.

Table A-19: Potential GHG Emission Benefits for Very Low Carbon Fuels Incentive

Proposed Project	Representative Supported Technologies	Emission Reductions per GGE (metric tons CO_2e/yr)	
		Per Fuel Type	Average
Very Low Carbon Fuels Incentive	Diesel Replacement Fuels (conservative CI of 40.80)	0.0063	0.0063
	Gasoline Replacement Fuels (conservative CI of 39.39)	0.0068	

Note: staff used the estimated emission reductions for diesel replacement fuels, as reflected in this analysis.

Table A-20 summarizes the annual criteria pollutant emission benefits for projects where the vehicle or equipment technology is known. For new projects, quantification of the criteria pollutant benefits will be determined during the solicitation process.

Table A-20: Potential Per Vehicle Annual Weighted Criteria Pollutant Emission Benefits

Phase	Proposed Project	Representative Supported Technologies	Per Vehicle Weighted Annual Criteria Pollutant Emission Reductions (tpy)	
			Per Technology Type	Average
Commercialization	CVRP	Battery-Electric LDVs	0.003	0.003
		Plug-In Hybrid LDVs	0.003	
	HVIP	Hybrid MHD Trucks	0.016	0.019
		Battery-Electric MHD Trucks	0.015	
		Battery-Electric Urban Buses	0.075	
	Low NOx Engines	Replacement of CNG with MHD Low NOx Engines Fueled with RNG	0.012	0.012
Transition	Truck Loan Assistance	Replacement of 1998 MY with 2008 MY HHD Trucks	0.178	0.281
		Replacement of 1998 MY with 2011 MY HHD Trucks	0.326	
	Agricultural Equipment Trade-Up Pilot[27]	Replacement of T2 with T4 & Replacement of T0 with T2	0.756	0.756
Pilot Projects to Benefit DACs	EFMP Plus-up	Hybrid LDVs	0.007	0.007
		Plug-In Hybrid LDVs	0.007	
		Battery-Electric LDVs	0.008	
	Public Fleets in DACs	Plug-In Hybrid LDVs	0.002	0.002
		Battery-Electric LDVs	0.003	

[27] For the Agricultural Equipment Trade-Up Pilot, emission reductions are shown per trade-up (i.e., two tractors), as shown in the preceding formula.

Cost Analysis

Staff analyzed the cost of each project, and for projects funded by AQIP, staff used the costs in a benefit-cost analysis. For this section, project costs are grouped in the following categories:

- Demonstration Phase Projects;
- Commercialization Phase Projects;
- Transition Phase Projects; and
- Pilot Projects to Benefit Disadvantaged Communities.

Demonstration Phase Projects: As discussed in previous Funding Plans, manufacturers are developing, testing, and proving technologies in the demonstration phase. Incentives are provided to help advance the development of technologies through demonstration projects focused on single vehicle prototypes to low-volume demonstration projects to advance the technology to the commercialization phase. In the demonstration phase, incentive funding levels are high because manufacturing is not standardized and is focused on smaller batches of vehicles. For projects in the demonstration phase, the high project costs were based on the potential funding amounts, assumed by staff, to be allocated to the proposed advanced technology demonstration projects.

Commercialization Phase Projects: For commercialization phase projects, funding support is assumed to be directly related to the incremental cost of advanced technologies. For example, HVIP currently provides vouchers to address the higher costs associated with advanced technology vehicles by offsetting a portion of incremental costs. For medium to heavy-duty commercialization phase projects, the incentives are based on current voucher amounts[28] provided for the various technologies and vehicle classes supported by the program.

Transition Phase Projects and Pilot Projects to Benefit Disadvantaged Communities: The proposed projects under these categories are primarily intended to support the penetration of advanced technology vehicles to benefit disadvantaged communities or support the purchase of commercialized clean technologies by economically challenged consumers. Moreover, transition phase project types have been established to increase market acceptance in disadvantaged communities or agricultural areas, unlike commercialization projects with the purpose to advance the widespread use of advanced technologies to reduce costs due to lower production volumes.

[28] https://www.californiahvip.org/docs/HVIP_Y4_Implementation%20Manual_2014-08-01.pdf

Project Costs

Based on the information provided on the previous page, staff determined the incentive levels for the proposed projects and supported technologies on a per vehicle basis. Table A-21 summarizes the proposed or estimated incentive levels for each of the projects.

Table A-21: Incentive Amounts for Projects and Supported Technologies

Phase	Proposed Projects	Representative Supported Technologies	Cost Per Technology	Average Cost	Additional Details
Demos	Advanced Technology Demonstrations	Battery-Electric Short/ Regional Haul Trucks	$500,000	$625,000	For the incentive amounts, staff assumed that 25% of the costs would be matched.
		Fuel Cell Short/Regional Haul Trucks	$750,000		
Commercialization	Zero-Emission Freight Pilot	Battery-Electric Yard Trucks	$80,000	$80,000	Staff assumed ARB would fund $80,000 towards the purchase of a battery-electric yard truck
	Zero-Emission Truck Pilot	Battery-Electric MHD Trucks	$500,000	$500,000	For the incentive amounts, staff assumed that 25% of the costs would be matched.
	Zero-Emission Bus Pilot	Battery-Electric Urban Buses	$500,000	$625,000	For the incentive amounts, staff assumed that 25% of the costs would be matched.
		Fuel Cell Urban Buses	$750,000		
	Rural School Bus Pilot	Renewable Diesel School Buses	$165,000	$237,500	Based on proposed incentive amounts; staff assumed that funding would be split equally between battery-electric school buses and renewable diesel school buses. To calculate the incentive amount for battery-electric school buses, staff took an average of small and large school buses.
		Battery-Electric School Buses	$310,000		
	CVRP	Plug-In Hybrid LDVs	$1,650	$2,250	Staff assumed 10% of CVRP rebates would go to low-income consumers for an increased rebate amount. For the average incentive amounts, staff applied the same technology split of 60% BEVs and 40% PHEVs.
		Battery-Electric LDVs	$2,650		
	HVIP	Battery-Electric Urban Transit Bus	$110,000	$34,665	For the average incentive amounts, staff applied the same technology split used in the emissions calculations, based on project data for historical funding amounts
		Hybrid MHD Truck	$22,000		
		Battery-Electric MHD Truck	$80,000		
	Low NOx Engines	Low NOx CNG Engines	$18,000	$18,000	Based on proposed incentive amounts
	Very Low Carbon Fuels Incentive	Very Low Carbon Fuels (40% of the 2010 LCFS base year, or lower)	$0.60	$0.60	Based on estimated incentive amounts; staff anticipate that the CI of incentivized fuels would vary, so to be conservative, staff used the average incentive amount for fuels from in-state feedstock and provide a DAC benefit.

Phase	Proposed Projects	Representative Supported Technologies	Cost Per Technology	Average Cost	Additional Details
Transition	Truck Loan Assistance	Replacement of a 1998 MY HHD Truck with 2008 or 2011 MYs	$10,000	$10,000	Based on historical project data
	Agricultural Equipment Trade-Up Pilot	Tier 4 Engines Replacing Tier 2, Subsequently Replacing Tier 0	$50,000	$50,000	Staff assumption based on $45,000 incentive for Tier 4 tractor purchase and $5,000 for the reconditioning and repair of Tier 2 tractor
Pilot Projects to Benefit DACs	EFMP Plus-up	Conventional Hybrid LDVs	$5,000	$6,125	For the average incentive amounts, staff applied the same technology split used the emissions calculations of 20% BEVs, 25% PHEVs, and 55% conventional hybrids and calculated incentive amounts based on the rebate amounts for moderate income levels.
		Plug-In Hybrid LDVs	$7,500		
		Battery-Electric LDVs	$7,500		
	Car Sharing Pilot Project	Battery-Electric LDVs	$14,000	$14,000	Based on data from a similar car share program in Buffalo
		Plug-In Hybrid LDVs	$14,000		
	Agricultural Worker Vanpools	Hybrid LHD Passenger Vans	$45,000	$45,000	Staff assumption based on estimated costs for all components for van conversion to hybrid system
	Public Fleets in DACs	Battery-Electric LDVs	$10,000	$7,625	Based on proposed incentive amounts
		Plug-In Hybrid LDVs	$5,250		
	Light-Duty Financing Assistance	Replacement with a Conventional Hybrid Vehicle, PHEV, or BEV Less than 8 Years Old	$10,500	$10,500	Staff estimates the average cost per loan, including the vehicle price buy down and loan loss reserve, will range from $9,000 to $12,000

Benefit-Cost Score Analysis

Staff analyzed the expected costs and developed cost-effectiveness scores for each project using well-established cost-effectiveness calculation methodology for incentives (consistent with that used in the Carl Moyer Memorial Air Quality Standards Attainment Program). In addition, to calculate cost-effectiveness, staff also applied an appropriate discount rate and utilized a capital cost recovery factor (CRF) in the analysis based on Carl Moyer Program Guidelines[29] to determine the annualized costs. Annualized cost is determined by the formula below:

$$Annualized\ Cost = CRF\ x\ incentive\ amounts\ for\ vehicles\ or\ equipment$$

[29] http://www.arb.ca.gov/msprog/moyer/guidelines/2011gl/2011cmpgl_20151218.pdf

A two percent discount rate[30] was used and the corresponding CRFs were determined based on the assumed usage life of the vehicles or equipment supported by the proposed projects. Table A-22 below shows the assumed vehicle or equipment usage life and the corresponding CRF values used to determine the annualized cost of the projects.

Table A-22: Vehicle Usage and Corresponding Cost Recovery Factors

Phase	Proposed Projects	Usage Life (Years)	CRF	Comments
Demos	Advanced Technology Demonstrations	3	0.35	Based on required minimum project life, although some technologies may be in use longer than 3 years
Commercialization	Zero-Emission Freight Pilot	15	0.08	Similar to HVIP, project life based on similar heavy-duty trucks
	Zero-Emission Truck Pilot	15	0.08	Similar to HVIP, project life based on similar heavy-duty trucks
	Zero-Emission Bus Pilot	15	0.08	Based on transit bus usage life of 15.1 years[31]
	Rural School Bus Pilot	15	0.08	Based on average school bus useful life of 15 years[32]
	CVRP	15	0.08	Project life is based on a 15 year vehicle life assumed by ARB staff. The assumption is based on the median life for passenger cars in California, which is 14 years, or 186,000 miles, and other factors.
	HVIP	15	0.08	Staff assumed a conservative usage life of 15 years, but trucks can have a useful life of over 20 years[33]
	Low NO_x Engines	3/15	0.08	Renewable fuel is required for 3 years; for engine usage life, assumed to be the same as vehicles under HVIP
Transition	Truck Loan Assistance Program	3	0.35	ARB's In-Use Truck and Bus Regulation[34] requires all 1999 or older MY trucks to be replaced by January 1, 2020
	Agricultural Equipment Trade-Up Pilot	5	0.21	Staff assumption based on expected remaining life of Tier 0 tractor, although the incentivized tractors are likely to be in service much longer

[30] http://www.arb.ca.gov/msprog/moyer/guidelines/2011gl/2011cmp_appg_20151218.pdf
[31] US Department of Transportation, Federal Transit Administration, Useful Life of Transit Buses and Vans, Report No. FTA VA-26-7229-07.1, April 2007. http://www.fta.dot.gov/documents/Useful_Life_of_Buses_Final_Report_4-26-07_rv1.pdf
[32] http://www.afdc.energy.gov/uploads/publication/case-study-propane-school-bus-fleets.pdf
[33] Jennings, G. and Brotherton, T. "Vehicle and Technologies Characterization and Baseline," California Hybrid, Efficient and Advanced Truck Research Center, http://www.calstart.org/Libraries/CalHEAT_Documents/Baseline_and_Preliminary_Pathways_Whitepaper.sflb.ashx
[34] http://www.arb.ca.gov/msprog/onrdiesel/documents/tbfinalreg.pdf

Phase	Proposed Projects	Usage Life (Years)	CRF	Comments
Pilot Projects to Benefit DACs	EFMP Plus-up	3	0.35	Staff assumption based on expected remaining useful life of baseline 1995 MY vehicle
	Car Share Pilot Project	3	0.35	Based on car share vehicle operating life[35]
	Agricultural Worker Vanpools	6	0.18	Staff assumption based on CalVans program
	Public Fleets in DACs	15	0.08	See CVRP comments
	Light-Duty Financing Assistance	3	0.35	Staff assumption based on expected maximum term of loan and vehicle ownership requirement, although the purchased vehicle will likely last longer

With the information presented above, a cost-effectiveness score was calculated for the proposed projects funded by AQIP. The cost-effectiveness of a project is determined by dividing the incentive amounts of an average vehicle or equipment supported by the proposed projects by the annual per-vehicle weighted emission reductions, as shown below.

$$\textit{Cost Effectiveness (\$/ton)} = \frac{Annualized\ Cost\ (^{\$}/_{year})}{Annual\ Per\ Vehicle\ WTW\ Emission\ Reductions(^{tons}/_{year})}$$

Table A-23 provides the inputs and the resulting weighted criteria pollutant cost-effectiveness of the projects funded by AQIP.

Table A-23: Weighted Criteria Pollutant Cost-Effectiveness

Proposed Projects	CRF	Emission Reduction (tpy)	Incentive levels ($)	Cost-Effectiveness ($/ton)
Truck Loan Assistance Program	0.35	0.28	$10,000	$12,340
Agricultural Equipment Trade-Up	0.21	0.76	$50,000	$14,013

The cost-effectiveness shown in the table above are in units of dollars per ton of criteria pollutant emissions reduced ($/ton). Per AB 8, the cost-effectiveness values were converted to a benefit-cost score based on pound of criteria pollutant emissions benefit per dollar spent (lbs/$). Finally, the cost-effectiveness scores for each project were given points based on a scale from 1 to 5 points. Those projects with a cost-effectiveness of less than $15,000 per ton of emissions reduced received a high of 5 points, because this cost-effectiveness level is within the range of allowable

[35] Shaheen, Susan and Adam Cohen. "Carsharing and Personal Vehicle Services: Worldwide Market Developments and Emerging Trends," International Journal of Sustainable Transportation, No. 7, pp. 5-34, 2010.

cost-effectiveness in other ARB incentive programs. The remaining bins were increased by $15,000 increments with the least cost-effective projects, those projects over $60,000 per ton of emissions reduced, receiving the lowest points possible. The cost-effectiveness scores for each project were then scored based on the scale to be used in the "Total Benefit Index" score for AB 8 project selection. The cost-effectiveness of each proposed project was scored based on the following scale and summarized in Table A-24:

5: Less than $15,000/ton
4: Greater than or equal to $15,000/ton and less than $30,000/ton
3: Greater than or equal to $30,000/ton and less than $45,000/ton
2: Greater than or equal to $45,000/ton and less than $60,000/ton
1: Greater than or equal to $60,000/ton

Table A-24: Final Cost-Effectiveness/Benefit-Cost Score and Corresponding Scaled Score for Total Benefit Index for AQIP Projects

Proposed Projects	Final Cost-Effectiveness ($/ton)	Benefit-Cost Score (lbs/$)	Scaled Score
Truck Loan Assistance Program	$12,340	0.16	**5**
Agricultural Equipment Trade-Up	$14,013	0.14	**5**

Additional Preference Criteria

The additional preference criteria may be used to provide additional funding preference in conjunction with the benefit-cost score shown above. As discussed further below, staff also evaluated additional preference criteria, as identified in AB 8. These criteria included:

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.
4. Ability to achieve GHG 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.

Recognizing the range of potential benefits and to ensure a robust mix of proposed projects to be funded, for quantitative preference criteria 1, 2, and 4, staff analyzed the associated data and equally divided the results into scoring ranks between 0 and 5, according to the following steps:

- Results for each specific additional preference criteria were quantified for each of the proposed projects.

- Scoring scale increments were established for each rank (0-5) to generate an equal distribution in points for the proposed projects. Additional information on the scales is discussed below for each additional preference criteria.
- The proposed projects are then ranked based on the scale (0-5) to be used in the "Total Benefit Index."

Staff anticipates 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:

1. *Proposed or potential reduction of criteria or toxic air pollutants* – This analysis considered the magnitude of emission reductions by quantifying the direct lifetime criteria pollutant emission reductions expected per average vehicle or piece of 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. Staff analyzed the emission benefits on a per vehicle basis to account for differences in vehicle sale volumes and statewide populations of the various vehicles supported by AQIP. Resulting total lifetime emission reductions ranged from less than 0.1 tons to 4.3 tons of lifetime criteria pollutant emission reductions per vehicle. The scoring scale associated within each rank (1-5) 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 0.3 ton increments. Projects with less than or equal to 0.3 tons of criteria pollutant emissions reduced receive 1 point, while those projects with greater than 1.5 tons of criteria pollutant emissions reduced receive 5 points. Below is the resulting scale for criteria pollutant emission reductions per vehicle:

   5: Greater than or equal to 1.5 tons
   4: Greater than or equal to 0.9 tons and less than 1.5 tons
   3: Greater than or equal to 0.6 tons and less than 0.9 tons
   2: Greater than or equal to 0.3 tons and less than 0.6 tons
   1: Less than 0.3 tons
   0: No Benefits

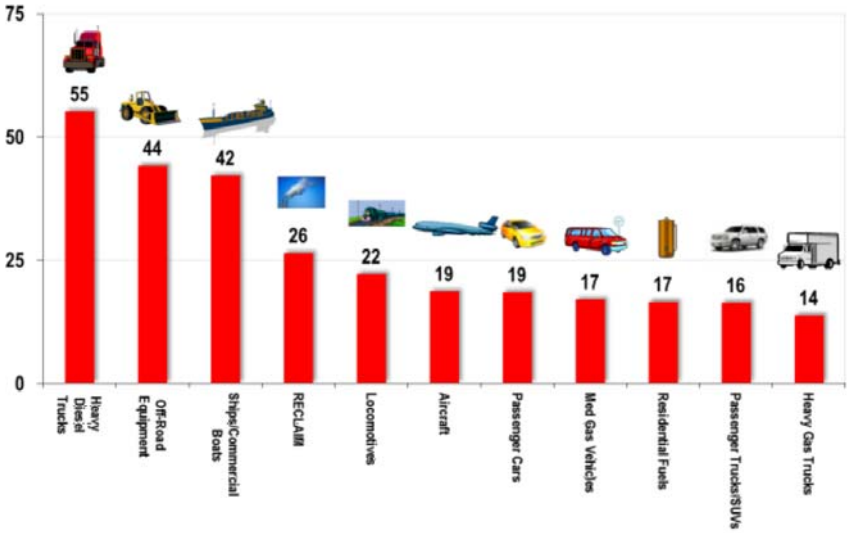
   Based on the information described above, Table A-25 summarizes the results and the corresponding score for this additional preference criterion.

Table A-25: Results for Additional Preference Criterion 1

Proposed Projects	Emission Reductions (tpy)	Project Life	Lifetime Emission Reductions (tons)	Score
Truck Loan Assistance Program	0.28	3	0.84	**3**
Agricultural Equipment Trade-Up	0.76	5	3.78	**5**

2. *Contribution to regional air quality improvement* – Staff developed a scoring scale based on the ARB emissions inventory for the largest region federally designated as an extreme non-attainment area in CA, and ranked projects based on their corresponding emissions inventory contributions from highest to lowest. Specifically, staff used the NOx emissions inventory in tons per day for 2023 in the South Coast Air Basin, found in ARB's Vision for Clean Air: A Framework for Air Quality and Climate Planning.[36] The ranking scale is based on the emissions inventory shown in Figure A-1.

Figure A-1: Largest South Coast NOx Emission Sources in Tons Per Day



NOx emission sources were ranked in tons per day for various vehicle and equipment types, ranging from heavy-duty gas trucks, at 14 tons per day, to heavy-duty diesel trucks, at 55 tons per day. The scoring scale associated with each rank (1-5) for this criterion was established by calculating the range of NOx emissions between the highest and lowest value, and dividing that range by five. As a result, the bins were rounded and scaled in 10-ton increments. Projects corresponding to inventory sources with less than or equal to 10 tons of NOx per

[36] Air Resources Board. (2013d). Vision for Clean Air: A Framework for Air Quality and Climate Planning; Public Review Draft. Appendix: Actions for Development, Demonstration, and Deployment of Needed Advanced Technologies.

day receive one point, while those projects with greater than 40 tons receive five points. The sources of emissions contribution were ranked based on the following scale:

5: Category contributes more than 40 tons of NOx per day
4: Category contributes between 31 and 40 tons of NOx per day
3: Category contributes between 21 and 30 tons of NOx per day
2: Category contributes between 11 and 20 tons of NOx per day
1: Category contributes between 1 and 10 tons of NOx per day

3. *Ability to promote the use of clean alternative fuels and vehicle technologies* – 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 vehicle technologies, or enabling technologies, such as hybrid or plug-in hybrid technologies. This qualitative analysis ranked projects by whether or not they used a clean low carbon alternative or renewable fuel or were clean vehicle technologies. Staff scored this preference criterion based on the following:

   5: Technologies that use low carbon alternative fuels <u>and</u> are a clean vehicle technology.
   3: Technologies that use low carbon alternative fuels <u>or</u> are a clean vehicle technology.
   0: Technologies that do not use clean alternative fuels and are not a clean vehicle technology.

4. *Ability to achieve GHG reductions* – Similar to the methodology established in the first preference criterion, staff conducted a lifetime well-to-wheels GHG emissions analysis for the vehicles and equipment supported by the proposed projects. Staff determined expected GHG emission reductions achieved for each vehicle or equipment funded by the proposed projects and found that GHG emission reductions were minimal. The bins were determined by taking the high and low resulting benefits, and scaled to try to develop an equal distribution of scores. Below is the resulting scale for GHG reductions per vehicle:

   5: Greater than or equal to 500 $MTCO_2e$
   4: Greater than or equal to 400 $MTCO_2e$ and less than 500 $MTCO_2e$
   3: Greater than or equal to 250 $MTCO_2e$ and less than 400 $MTCO_2e$
   2: Greater than or equal to 50 $MTCO_2e$ and less than 250 $MTCO_2e$
   1: Less than or equal to 50 $MTCO_2e$
   0: No GHG emission reductions

   Based on the information described above, Table A-26 summarizes the results and the corresponding score for this additional preference criterion.

Table A-26: Results for Per Vehicle Additional Preference Criterion 4

Proposed Projects	GHG Emission Reduction (metric tons CO2e)	Project Life	Total GHG Emission Reduction (metric tons CO2e)	Score
Truck Loan Assistance Program	N/A	3	N/A	**0**
Agricultural Equipment Trade-Up Pilot	N/A	5	NA	**0**

5. *Ability to support market transformation of California's vehicle or equipment fleet to utilize low carbon or zero-emission technologies* – Similar to criterion 3 above, this qualitative analysis ranked projects by whether or not technologies that support market transformation are supported by the proposed projects. Staff used ARB's Vision for Clean Air document as a key reference in scoring technologies for this evaluation. Light-duty PHEVs, BEVs, and FCEVs, for example, are considered transformative technologies that will help the State meet its air quality goals. Staff scored this preference criterion based on the following:

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

6. *Ability to leverage private capital investments* – Staff is not proposing to include this criterion for FY 2016-17 as staff is working 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.

<u>Total Benefit Index</u>

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 weighting) with additional preference scores (weighted at 25 percent). 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 A-27 summarizes the scores for all projects and the Total Benefit Index score for all of the AQIP projects currently proposed in the FY 2016-17 Funding Plan.

Table A-27: Project Scores and Total Benefit Index Score of Proposed Projects

Proposed Projects	Additional Preference Criteria					**25% of TBI**	**75% of TBI**	**Total Benefit Index Score**
	Proposed or potential reduction of criteria or toxic air pollutants.	Contribution to regional air quality improvement.	Ability to promote the use of clean fuels and technologies	Ability to achieve GHG reductions	Ability to support market transformation	**Average of Additional Preference Criteria Score**	**Benefit Cost Score**	
Truck Loan Assistance Program	3	5	3	0	0	**2.2**	**5**	**4.3**
Agricultural Equipment Trade-Up Pilot	5	5	3	0	5	**3.6**	**5**	**4.7**

Lifetime Emission Reductions Analysis

To determine the potential emission reductions for each project, staff estimated the number of vehicles or volume of fuels that could be funded, based on current project data or using the proposed allocations in the Funding Plan and the average per vehicle incentive amounts listed in Table A-21. Table A-28 summarizes the number of vehicles and volume of fuels that are reasonably expected to be funded based on the proposed allocations.

Table A-28: Potential Number of Vehicles or Volume of Fuels Funded with Proposed Allocations

Phase	Proposed Projects	Proposed FY16/17 Allocation	Average Cost	# of Vehicles/ Volume of Fuels Funded[37]	Comments
Demos	Advanced Technology Demonstrations	$59,000,000	$625,000	90	
Commercialization	Zero-Emission Freight Pilot	$5,000,000	$80,000	60	
	Zero-Emission Truck Pilot	$18,000,000	$500,000	66	Staff assumption for number of vehicles funded is based on applications received from the FY15-16 Zero-Emission Truck and Bus Pilot Solicitation
	Zero-Emission Bus Pilot	$42,000,000	$625,000	43	Staff assumption for number of vehicles funded is based on applications received from the FY15-16 Zero-Emission Truck and Bus Pilot Solicitation
	Rural School Bus Pilot	$10,000,000	$237,500	40	
	CVRP	$230,000,000	$2,250	98,000	
	HVIP	$18,000,000	$34,665	500	
	Low NOx Engines	$23,000,000	$18,000	1,200	
	Very Low Carbon Fuels Incentive	$40,000,000	$0.60	67,000,000	
Transition	Truck Loan Assistance	$22,000,000	$10,000	3,900	Estimated number of vehicles funded assumes that ARB will pay a contribution rate of 4% for top tier loans, which approximately doubles the leveraged funds
	Agricultural Equipment Trade-Up Pilot	$3,000,000	$50,000	50	
Pilot Projects to Benefit DACs	EFMP Plus-up	$30,000,000	$6,125	4,900	
	Car Sharing Pilot Project	$8,000,000	$14,000	550	
	Public Fleets in DACs	$3,000,000	$7,625	400	
	Agricultural Worker Vanpools	$3,000,000	$45,000	60	
	Light-Duty Financing Assistance	$6,000,000	$10,500	550	

[37] Estimate includes administrative costs, when applicable

Finally, to determine the total potential emission reductions over the course of the project life for each project proposed in the Funding Plan, staff used the following formula:

$$Total\ Project\ Emission\ Reduction = Annual\ Emission\ Reductions\ per\ Vehicle\ x\ Project\ Life\ x\ \#\ of\ Vehicles\ Funded$$

Table A-29 displays the total weighted criteria pollutant emission reductions for AQIP and projects that until recently were traditionally funded through AQIP using the formula shown above.

Table A-29: Total Potential Criteria Emission Reductions

Phase	Proposed Project	Per Vehicle Average (tons)	Project Life (years)	Total per Vehicle Lifetime Emission Reductions (tons)	Number of Vehicles Funded	Total Lifetime Criteria Pollutant Emission Reductions (tons)
Commercialization	CVRP	0.003	15	0.044	98,000	4,307
	HVIP	0.019	15	0.283	500	142
	Low NOx Engines	0.012	15	0.183	1,200	220
Transition	Truck Loan Assistance	0.281	3	0.844	3,900	3,290
	Agricultural Equipment Trade-Up Pilot	0.756	5	3.782	50	189
Pilot Projects to Benefit DACs	EFMP Plus-up	0.007	3	0.021	4,900	104
	Public Fleets in DACs	0.002	15	0.037	400	15

Finally, Table A-30 displays the total potential GHG emission reductions for each project based on the methodology and assumptions outlined throughout this appendix.

Table A-30: Total Potential GHG Emission Reductions

Phase	Proposed Project	Per Vehicle Average	Project Life (years)	Total per Vehicle Lifetime Emission Reductions	Number of Vehicles or Equipment Funded	Total Lifetime GHG Emission Reductions (metric tons CO_2e)
Demonstration	Advanced Technology Demonstrations	50.70	3	152.11	90	13,690
Commercialization	Zero-Emission Freight Pilot	53.93	15	808.96	60	48,538
	Zero-Emission Truck Pilot	24.67	15	370.12	66	24,428
	Zero-Emission Bus Pilot	60.01	15	900.13	43	38,705
	Rural School Bus Pilot	16.88	15	253.17	40	10,127
	CVRP	2.56	15	38.39	98,000	3,762,249
	HVIP	8.56	15	128.33	500	64,164
	Low NOx Engines	26.20	3	78.59	1,200	94,304
	Very Low Carbon Fuels Incentive	0.006	N/A	N/A	67,000,000[38]	424,020
Transition	Truck Loan Assistance	N/A	3	N/A	3,900	N/A
	Agricultural Equipment Trade-Up Pilot	N/A	5	N/A	50	N/A
Pilot Projects to Benefit DACs	EFMP Plus-up	1.73	3	5.19	4,900	25,419
	Car Sharing Pilot Project	1.64	3	4.92	550	2,707
	Agricultural Worker Vanpools	5.30	6	31.79	60	1,908
	Public Fleets in DACs	2.13	15	31.95	400	12,782
	Light-Duty Financing Assistance	2.24	3	6.71	550	3,688

[38] Based on volume of fuel funded (in gallons)

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