CALIFORNIA ENERGY COMMISSION

California Energy Commission

COMMISSION REPORT

Draft 2021 Integrated Energy Policy Report

Appendix: Assessing the Benefits and Contributions of the Clean Transportation Program

Gavin Newsom, Governor

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California Energy Commission

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ABSTRACT

The *2021 Integrated Energy Policy Report* provides the results of the California Energy Commission's assessments of a variety of energy issues facing California. Many of these issues will require action if the state is to meet its climate, energy, air quality, and other environmental goals while maintaining reliability and controlling costs.

The year 2021 has been unprecedented as the state continues to face the impacts and repercussions of challenging events, including the continued effects of the COVID-19 pandemic, extreme summer weather, and drought conditions. In addition to these events, the *2021 Integrated Energy Policy Report* covers a broad range of topics, including building decarbonization, energy efficiency, challenges with decarbonizing California's gas system, quantifying the benefits of the Clean Transportation Program, and the *California Energy Demand Forecast*.

Keywords: Integrated Energy Policy Report, Clean Transportation Program, benefits, zero-emission vehicles

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CHAPTER 1:
The Clean Transportation Program Is Essential to Achieving California Policies

California has a broad set of laws and executive orders designed to address climate change and serve as a leader for innovative climate action. These include mandated statewide greenhouse gas (GHG) emissions reductions, clean electricity requirements, policies to support cleaner air, zero-emission vehicle (ZEV) sales and operation goals, and a broader goal to achieve a net-zero-emission economy. Several states follow California's lead when designing or implementing clean air and climate strategies. Table 1 below highlights several of these policies and transformational goals to convert vehicles to zero-emission.

Table 1: Major Clean Transportation Policies

Policy Action	Leading Objectives
Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016)	40 percent reduction in statewide GHG emissions relative to 1990 levels by 2030.
Senate Bill 100 (De León, Chapter 312, Statutes of 2018)	60 percent renewable electricity by 2030. 100 percent renewable or zero-carbon electricity by 2045.
Executive Order B-55-18	Carbon neutrality by 2045.
Clean Air Act; California State Implementation Plans	80 percent reduction in oxides of nitrogen (NO_x) by 2031.
Executive Order B-16-12	1.5 million ZEVs by 2025.
Executive Order B-48-18	5 million ZEVs on the road by 2030. 250,000 electric charging stations, including 10,000 direct current (DC) fast chargers, as well as 200 hydrogen stations by 2025.
Executive Order N-79-20	100 percent of new light-duty vehicle sales are ZEVs by 2035. 100 percent of operating drayage trucks, off-road vehicles, and off-road equipment are ZEVs by 2035, where feasible. 100 percent of operating trucks and buses are ZEVs by 2045, where feasible.

Source: CEC

In 2007, the California Legislature passed Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007),[1] modifying the Health and Safety Code (Section 44272) to create the Clean Transportation Program (formerly known as Alternative and Renewable Fuel and Vehicle Technology Program). With up to $100 million in funding per year by a surcharge on vehicle registrations and smog abatement fees, the Clean Transportation Program funds projects that will "develop and deploy innovative technologies that transform California's fuel and vehicle types to help attain the state's climate change policies."[2] In 2013, the California Legislature reauthorized this program with Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013), extending the Clean Transportation Program to January 1, 2024.

As established in AB 118, the California Energy Commission (CEC) has developed an Investment Plan and updates it each year to determine funding priorities and opportunities for the Clean Transportation Program, with an emphasis on the subsequent fiscal year. The *2021–2023 Investment Plan Update* (the most recent edition) will be taken to a business meeting for possible adoption later this year.[3]

The Clean Transportation Program does not operate in a vacuum but within a context of several state funding programs, vehicle regulations, and agency collaborations. These include vehicle regulations and incentives developed by the California Air Resources Board (CARB), low-carbon fuel standards developed by CARB, infrastructure investments by investor-owned utilities overseen by the California Public Utilities Commission (CPUC), and broader business coordination with the Governor's Office of Business and Economic Development (GO-Biz). There is strong collaboration among the agencies on a regular basis and through the ZEV Market Development Strategy, spearheaded by GO-Biz.[4] The projects supported by the Clean Transportation Program interact with and are informed by these other efforts.

CEC Is the State's Primary ZEV Infrastructure Planning Agency

The Clean Transportation Program benefits from and is informed by the CEC's leadership in ZEV infrastructure analyses directed through statute. Assembly Bill 2127 (Ting, Chapter 365, Statutes of 2018) requires the CEC to prepare a statewide assessment of the charging infrastructure needed to achieve the goal of 5 million ZEVs on the road by 2030 and reduce

1 Assembly Bill 118 (Núñez, Statutes of 2007, Chapter 750). Subsequently modified by Assembly Bill 109 (Núñez, Statutes of 2008, Chapter 313).

2 Health and Safety Code Section 44272 (a).

3 CEC. [2021-2023 Investment Plan Update for the Clean Transportation Program](https://www.energy.ca.gov/publications/2021/2021-2023-investment-plan-update-clean-transportation-program). https://www.energy.ca.gov/publications/2021/2021-2023-investment-plan-update-clean-transportation-program.

4 GO-Biz. February 2021. [California Zero-Emission Vehicle Market Development Strategy](https://static.business.ca.gov/wp-content/uploads/2021/02/ZEV_Strategy_Feb2021.pdf). https://static.business.ca.gov/wp-content/uploads/2021/02/ZEV_Strategy_Feb2021.pdf.

emissions of GHGs to 40 percent below 1990 levels by 2030. Executive Order N-79-20[5] subsequently required the CEC to assess the infrastructure needed to achieve full ZEV adoption within the coming decades. The recent CARB Mobile Source Strategy approximated this trajectory to include about 8 million light-duty ZEVs and 180,000 medium- and heavy-duty ZEVs by 2030 (including plug-in electric vehicles and fuel cell electric vehicles).[6]

The inaugural AB 2127 report, published by the CEC in June 2021, finds that nearly 1.2 million public and shared private chargers are needed to support almost 8 million light-duty ZEVs in 2030.[7] Past 2030, the ZEV population will continue to grow, along with the need for additional charging infrastructure. For medium- and heavy-duty charging in 2030, 157,000 chargers are needed to support 180,000 ZEVs. The report also concludes that, although the private market will ultimately be necessary for ZEV refueling in the future, targeted and innovative state efforts are necessary in the near term to build toward a sustainable private market for charging infrastructure that can support a reliable, decarbonizing grid.

Senate Bill 1000 (Lara, Chapter 368, Statutes of 2018) also directs the CEC to assess electric vehicle (EV) infrastructure deployment. Results from the inaugural 2020 analysis showed that public chargers are collocated with EVs but unevenly distributed by income, population density, and geography. Low-income communities have the fewest chargers per capita and the widest range of drive times to chargers compared to middle- and high-income communities.[8] For the underway 2021 analysis, the CEC is focusing on drive times to DC fast charging as another key metric of charging equity and access.[9] This analysis is ongoing, and results will help inform equitable EV infrastructure deployment under the Clean Transportation Program.

In addition to extending the Clean Transportation Program through the end of 2023, AB 8 directs the CEC and CARB to jointly prepare an annual report on the time and cost needed to

5 Governor Gavin Newsom. Executive Order N-79-20. September 2020. https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-Climate.pdf.

6 *Draft 2020 Mobile Source Strategy,* https://ww2.arb.ca.gov/sites/default/files/2021-04/Revised_Draft_2020_Mobile_Source_Strategy.pdf.

7 Alexander, Matt, Noel Crisostomo, Wendell Krell, Jeffrey Lu, and Raja Ramesh. July 2021. Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment: Analyzing Charging Needs to Support Zero-Emission Vehicles in 2030 – Commission Report. California Energy Commission. Publication Number: CEC-600-2021-001-CMR. https://efiling.energy.ca.gov/getdocument.aspx?tn=238853.

8 Hoang, Tiffany. 2020. California Electric Vehicle Infrastructure Deployment Assessment: Senate Bill 1000 Report. California Energy Commission. Publication Number: CEC-600-2020-009. https://efiling.energy.ca.gov/GetDocument.aspx?tn=236189&DocumentContentId=69167.

9 Staff presentation at July 8, 2021 workshop. https://efiling.energy.ca.gov/GetDocument.aspx?tn=238717&DocumentContentId=72119.

attain 100 hydrogen refueling stations within the state. The 2020 report estimates that California will have 105 open retail stations before 2024.[10] Executive Order B-48-18[11] set a subsequent goal of 200 stations by 2025. The Clean Transportation Program has been critical in building the momentum toward both goals.

Requirements for Assessing the Clean Transportation Program

In 2008, the Legislature passed Assembly Bill 109 (Núñez, Chapter 313, Statutes of 2008), which modifies Section 44273 of the Health and Safety Code to require the CEC to produce a benefits report for the Clean Transportation Program. The benefits report is part of the Commission's broader *Integrated Energy Policy Report (IEPR)*, published biennially. The report shall include:

1. A list of projects funded by the Alternative and Renewable Fuel and Vehicle Technology Fund.[12]
2. The expected benefits of the projects in terms of air quality, petroleum use reduction, GHG emissions reduction, technology advancement, benefit-cost assessment, and progress toward achieving these benefits.
3. The overall contribution of the funded projects toward promoting a transition to a diverse portfolio of clean, alternative transportation fuels and reduced petroleum dependency in California.
4. Key obstacles and challenges to meeting these goals identified through funded projects.
5. Recommendations for future actions.

This appendix to the *2021 IEPR* serves as the benefits report for 2021. Past benefits reports have been similarly included in previous biennial years' IEPRs.

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10 Baronas, Jean, Gerhard Achtelik, et al. 2020. Joint Agency Staff Report on Assembly Bill 8: 2020 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California. California Energy Commission and California Air Resources Board. Publication Number: CEC-600-2020-008. https://www.energy.ca.gov/sites/default/files/2021-05/CEC-600-2020-008.pdf

11 Former Governor Edmund G. Brown Jr. Executive Order B-48-18. January 2018.

12 A map of Clean Transportation Program projects, with a downloadable list of projects, is available online. Clean Transportation Program — Overview. https://caenergy.maps.arcgis.com/home/item.html?id=c31b46862d884112aa8a767de499ae28.

Funding Summary and Highlights of the Clean Transportation Program

The Clean Transportation Program has provided more than $1 billion in funding through the program since 2009. In many cases, projects are in progress, with ongoing siting, installation, construction, and demonstrations.

Table 1 summarizes the investments of the program, including the following highlights:

- Installed or planned 15,154 chargers for plug-in electric vehicles, including:
    - 4,277 at multifamily and single-family homes.
    - 155 for fleets.
    - 419 at workplaces
    - 8,454 public and shared private Level 2 and Level 1 chargers.
    - 1,601 public DC fast chargers and 248 Level 2 chargers along highway corridors and urban metropolitan areas.
- Created the California Electric Vehicle Infrastructure Project (CALeVIP) to provide streamlined Clean Transportation Program incentives for light-duty EV charging infrastructure. In September 2021, the CEC announced two proposed successor block grant projects to build upon the successes and lessons learned under CALeVIP.
- Funded 83 new or upgraded publicly available hydrogen-fueling stations, approval to fund an additional 73 stations based on deployment progress, funding availability, and Clean Transportation Program Investment Plan Update funding allocations. An additional 23 privately funded stations are under development that will help serve an emerging population of fuel cell EVs. Once built, the 179 stations will exceed the 100 hydrogen-fueling stations called for by AB 8. As of July 2021, 52 hydrogen fueling stations were open for retail in California.
- Funded the development of retail fueling standards through an agreement with the California Department of Food and Agriculture, Division of Measurement Standards to standardize and allow hydrogen fuel dispensing on a per-kilogram basis.
- Launched the nation’s first commercial vehicle fleet incentive project, Energy Infrastructure Incentives for Zero-Emission Commercial Vehicles (EnergIIZE) to accelerate the deployment of infrastructure needed to fuel zero-emission trucks, buses, and equipment. The project will use a concierge-like model working directly with eligible applicants to help plan and fund the purchase of charging and hydrogen fueling infrastructure. The $50 million multiyear project will help communities most impacted by transportation-related pollution by meeting essential infrastructure needs.
- Funded 27 manufacturing projects supporting in-state economic growth and job creation, developing a supply chain for EVs and infrastructure, and positioning businesses for growth and scale.
- Provided workforce training for more than 20,000 trainees and 277 businesses and invested in preparing workers for the clean transportation economy that lead to

sustainable wages and translate clean technology investments into sustained employment opportunities.

- Launched 71 projects to promote the production of sustainable, low-carbon alternative fuels within California, with a cumulative annual production capacity equivalent to more than 158 million gallons of diesel fuel. Most will use waste-based feedstocks, such as dairy manure and municipal solid waste, which complement the Low Carbon Fuel Standard, a 2009 CARB regulation with a goal of reducing the overall carbon intensity of fuels within the transportation sector by 20 percent by 2030.
- Announced the availability of up to $7 million in grant funds for projects to design, engineer, construct, install, test, operate, and maintain a hydrogen plant in California that will produce 100 percent renewable hydrogen from in-state renewable resource(s). The plant, once constructed and operational, will be a source of 100 percent renewable hydrogen that will be used for transportation fuel. Projects will produce hydrogen that will meet California regulations when dispensed at the station for use in on-road fuel cell EVs, both light-duty and medium- and heavy-duty.

Table 2: Clean Transportation Program Investments as of August 2021

Funded Activity	Cumulative Awards to Date (in Millions)*	# of Projects or Units
Alternative Fuel Production		
Biomethane Production	$67.86	26 Projects
Gasoline Substitutes Production	$26.94	14 Projects
Diesel Substitutes Production	$63.91	26 Projects
Renewable Hydrogen Production	$7.93	2 Projects
Alternative Fuel Infrastructure		
Electric Vehicle Charging Infrastructure**	$192.60	15,154 chargers
Hydrogen Fueling Infrastructure (Including Operations and Maintenance)	$166.82	83 Public Fueling Stations
Medium- and Heavy-Duty ZEV Infrastructure	$99.11	75 Projects
E85 Fueling Infrastructure	$3.61	21 Fueling Stations
Upstream Biodiesel Infrastructure	$3.98	5 Infrastructure Sites
Natural Gas Fueling Infrastructure	$24.11	70 Fueling Stations
Alternative Fuel and Advanced Technology Vehicles		
Natural Gas (NG) and Propane Vehicle Deployment, Hybrid and ZEV Deployment (Including Clean Vehicle Rebate Project, California Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project, and Low-Income Mobility Incentives), and Advanced Technology Freight and Fleet Demonstrations	$250.40	14,516+ NG, Propane, Hybrid and ZEVs and 54 Demonstrations
Related Needs and Opportunities		
Manufacturing	$55.32	27 Manufacturing Projects
Workforce Training and Development	$33.33	20,000 Trainees
Fuel Standards and Equipment Certification	$3.90	1 Project
Sustainability Studies	$2.04	2 Projects
Regional Alternative Fuel Readiness	$24.15	55 Regional Plans
Centers for Alternative Fuels	$5.41	5 Centers
Technical Assistance and Program Evaluation	$17.52	N/A
Total	**$1.049 Billion**	

Source: CEC. *Includes all agreements that have been approved at a CEC business meeting or are expected for business meeting approval following a notice of proposed award. For canceled and completed projects, includes only funding received. **Includes $176.68 million for the California Electric Vehicle Infrastructure Project to provide EV incentives throughout California, which will fund a yet-to-be-determined number of EV chargers.

Using funds from the Clean Transportation Program, the CEC has also leveraged the additional investment of more than $734 million in private and other public funds. However, this amount represents only the minimal, contractually obligated amount of match funding provided toward

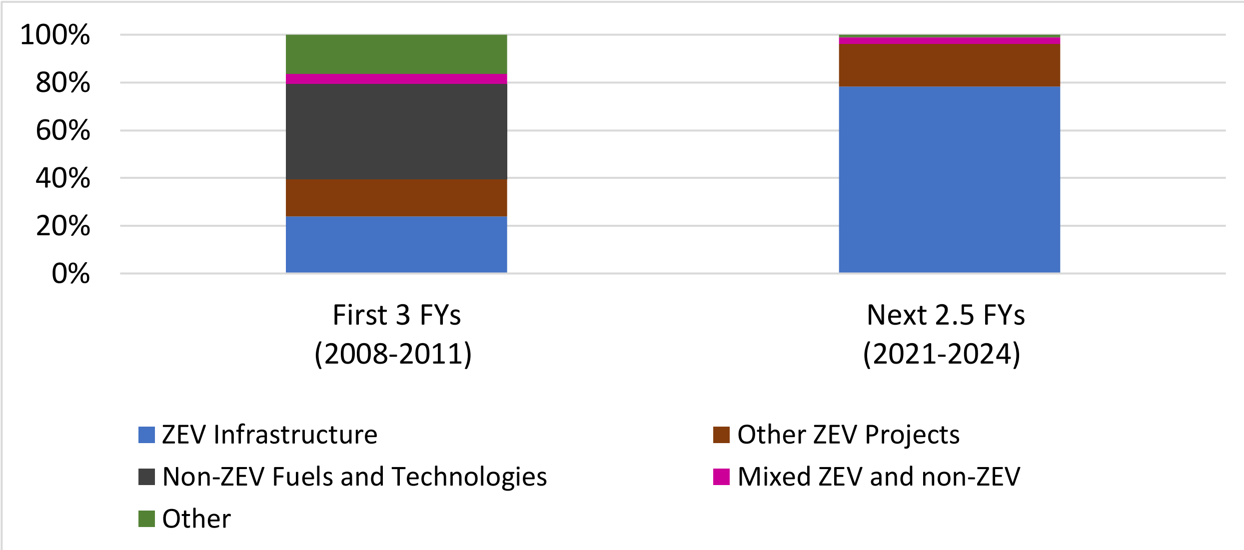
Clean Transportation Program projects; the actual amount of investment prompted by the Clean Transportation Program funding exceeds this amount.

State Policy and Funding Shift Toward ZEVs and ZEV Infrastructure

Funding under the Clean Transportation Program has transitioned significantly toward ZEV infrastructure and ZEV-related investment categories since the inception of the program more than 10 years ago. This shift, chronicled in each fiscal year's Investment Plan Update, reflects an increased regulatory transition toward zero-emission technologies to meet the state's climate and air quality goals, as well as the technological and market opportunities that have grown over time in the zero-emission sector. The shift is visible in Figure 1. The column on the left represents the combined share of funding across the first three fiscal years of the program (2008–2009, 2009–2010, and 2010–2011), while the column on the right represents the proposed share of funding for the next 2.5 fiscal years of the program (2021–2022, 2022–2023, and 2023–2024).[13]

13 Future fiscal year appropriations are subject to appropriations within future state budgets. Past and current investment plans are available at https://www.energy.ca.gov/programs-and-topics/programs/clean-transportation-program/clean-transportation-program-investment-0.

Figure 1: Program Funding Has Shifted Toward ZEV Infrastructure and Other ZEV Investments



Source: CEC

CHAPTER 2: Contributions of the Clean Transportation Program to a Clean Transportation Future

With a legislative mandate to fund clean transportation alternatives to those powered by petroleum, the Clean Transportation Program serves a key role to support the state's transition to a zero-emission future. If there are segments where zero-emission technology is not feasible, the program will also support near-zero-emissions technologies. Over the years, the program has evolved, being highly responsive to the ever-changing market conditions, technological innovations, and regulatory landscape.

Light-Duty Plug-In Electric Vehicle (PEV) Charging

PEVs can be charged from a standard electrical outlet, but the charging rate is rather low, with only about four miles of range added per hour. The Clean Transportation Program has funded projects that provide higher power chargers, known as Level 2 (L2) and direct current fast chargers (DCFC). There is some variation within these charger classes, but L2 chargers can generally add about 23 miles of range per hour, and DCFC can add hundreds of miles of range in an hour or sometimes even a half hour.

Table 3 presents the number and types of chargers the Clean Transportation Program has funded. However, the Clean Transportation Program has existing projects in place to deploy more than 20,000 L2 chargers and more than 1,700 DCFCs by 2024. Staff expects that additional funding based on new funding from the State Budget Act of 2021 will add tens of thousands of additional chargers, positioning the state to meet its 2025 goal of 250,000 chargers, which includes 10,000 DCFCs.

Table 3: Chargers Funded by the Clean Transportation Program as of May 31, 2021

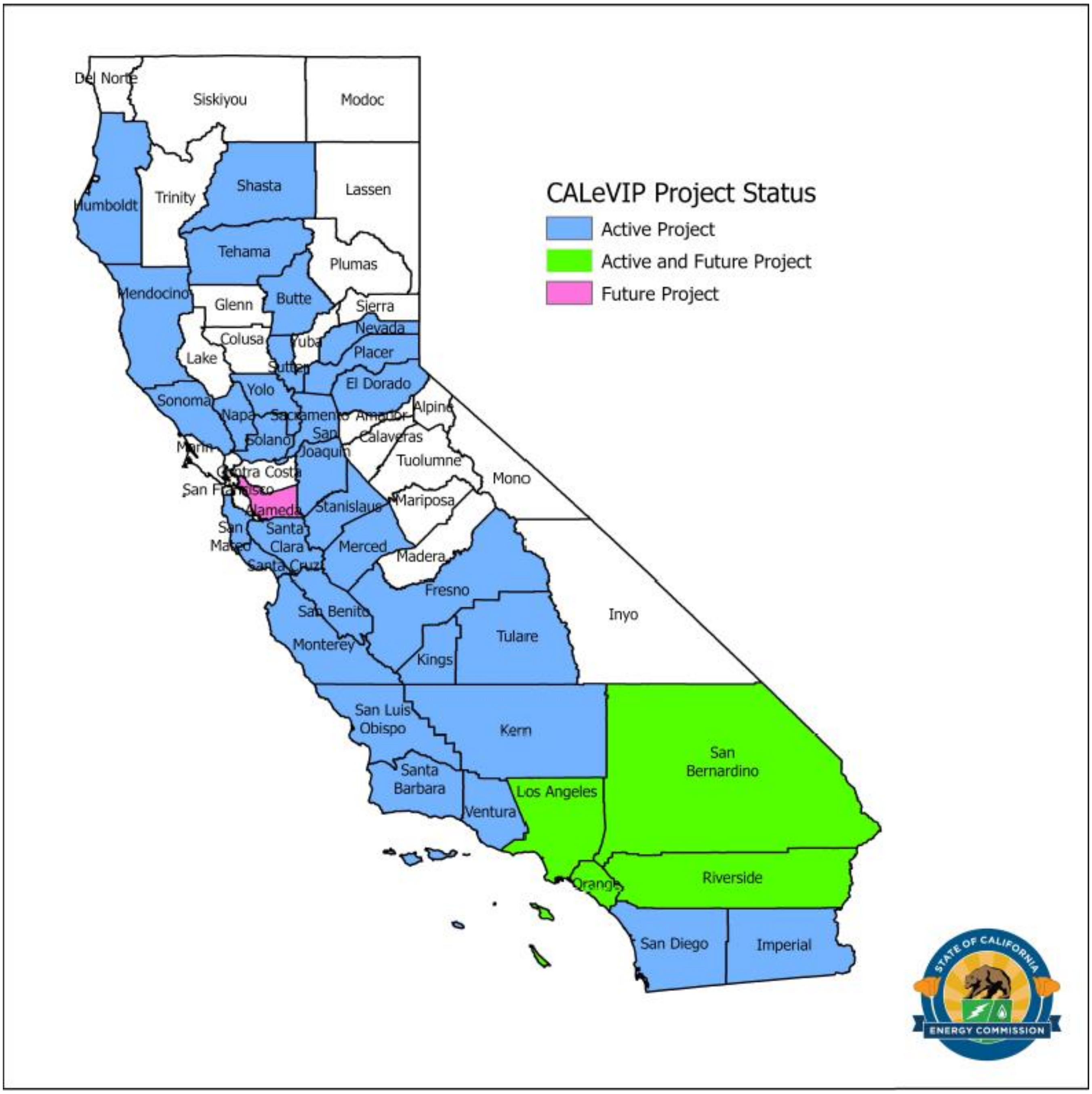
	Private Access	Shared Private Access	Shared Private Access	Shared Private Access	Public Access	Public Access	Mixed Access	Total
Charger Type / Setting	Level 2 - Residential (Single & Multifamily)	Level 2 - Fleet	Level 1 and Level 2 – Workplace	Level 2 – Residential (Multifamily)	Level 1 and Level 2 - Public	Level 2 and DCFC - Corridor/ Urban Metro	Level 2 and DCFC - California Electric Vehicle Infrastructure Project (CALeVIP)*	-
Installed	3,936	155	419	341	3,090	482	950	**9,373**
Planned	0	0	0	0	18	52	5,711	**5,781**
Total	**3,936**	**155**	**419**	**341**	**3,108**	**534**	**6,661**	**15,154**

Source: California Energy Commission (CEC). Does not include chargers that have yet to be approved at a CEC business meeting or connectors that have yet to be funded under CALeVIP. *Planned CALeVIP chargers = number of chargers with rebate funding reserved. "Mixed Access" includes shared private and public access chargers.

CALeVIP

The Clean Transportation Program has evolved over the years to maximize efficient deployment and reduce costs because of economies of scale. CALeVIP is a block grant project that provides incentives for the purchase and installation of electric vehicle charging infrastructure in targeted regions throughout the state. The funding is targeted at regions that have low rates of infrastructure installation or lack adequate incentives from utilities and other sources. To date, CALeVIP has launched ten regional incentive projects covering 32 counties in the state.

Figure 2: Counties Covered by CALeVIP Incentive Projects



Source: CEC

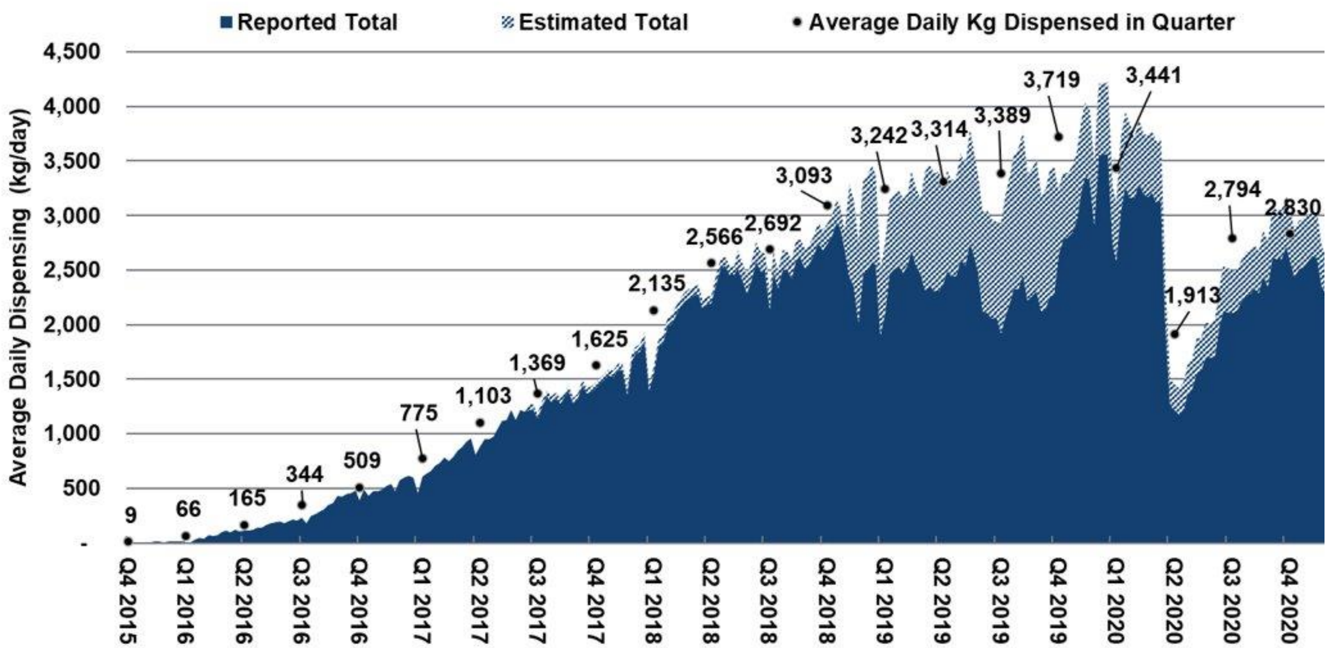
As the PEV ecosystem has developed over the years, it has become increasingly clear that some unique challenges remain for statewide deployment of charging infrastructure for all Californians. With this consideration, the Clean Transportation Program has also developed smaller projects aimed at more difficult applications and circumstances.

For example, the BESTFIT Innovative Charging Solutions solicitation sought applications in light-duty charging solutions that are uniquely suited to the local built environment, use case, and vehicle type. Goals for light-duty applicants included increasing charger use, minimizing installation and operation costs, and demonstrating advancements in the customer-charging interface. Nine innovative light-duty charging solution projects were selected for funding, in addition to six projects targeting the medium- and heavy-duty vehicle sector. In June 2021, the CEC also presented additional concepts for addressing the charging needs of rural communities and multifamily housing settings, with solicitations tentatively expected to be released by the end of 2021. More recently, a solicitation focused on Charging Access for Reliable On-demand Transportation Services (CARTS) will support electric vehicle (EV) charging infrastructure for high-mileage, on-demand transportation services such as ride-hailing, taxis, and meal and grocery delivery services.

Public Hydrogen Stations

Through the second quarter of 2021, 10,557 fuel cell electric vehicles (FCEVs) have been sold. There are an estimated 8,935 FCEVs registered and operating in California. To fuel these vehicles, 52 retail hydrogen refueling stations are open, with another 31 planned and under contract through the Clean Transportation Program. The expected total station capacity of these existing and planned stations is 69,000 kilograms per day, enough to support 98,000 FCEVs. This rate of deployment shows that station development is staying well ahead of FCEV deployment. Future funding of stations supported by the Clean Transportation Program, along with several completely privately funded stations, will be sufficient to support the fueling needs of nearly 230,000 FCEVs. Figure 3 highlights the growth in hydrogen dispensed in the state, predominantly at CEC-funded stations (with a significant interruption at the start of the COVID-19 pandemic beginning in the first quarter of 2020).

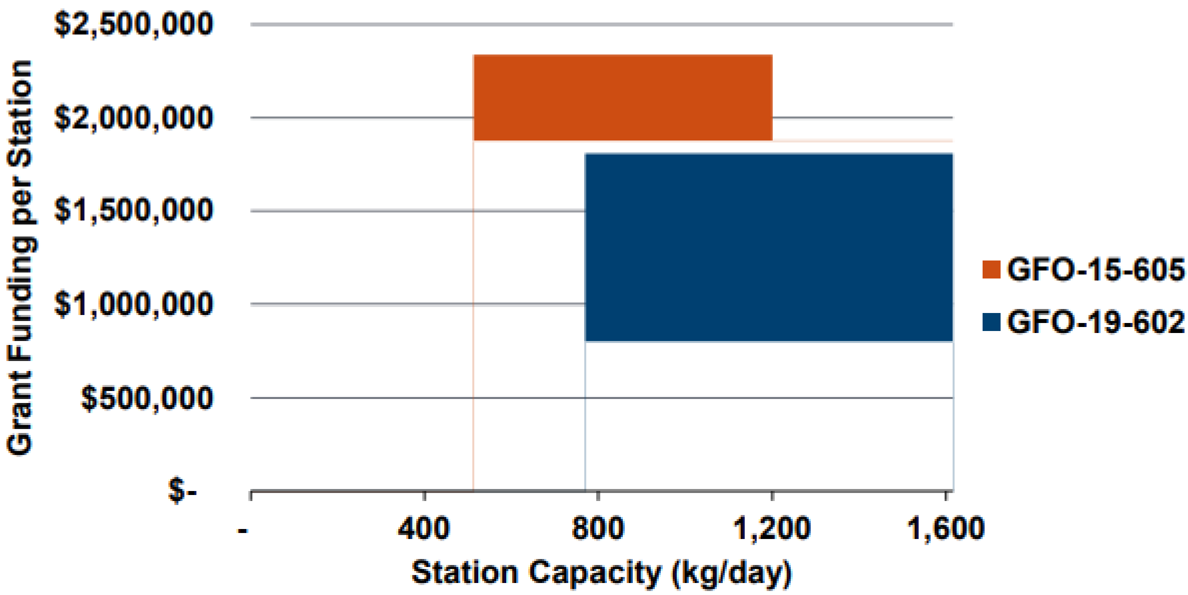
Figure 3: Average Hydrogen Dispensing per Day (2015–2020)



Source: CEC

The needs and capabilities of hydrogen stations funded under the Clean Transportation Program have evolved over time. In early stations, there was typically one hydrogen dispenser that was often located on the edge of a gasoline station property, and station capacity was in the range of 180 to 350 kilograms per day. Stations funded under GFO-15-605 (with first proposed awards in February 2017) ranged from 500 to 1,200 kilograms per day and mostly have two hoses for fueling. Under GFO-19-602 (with first proposed awards in September 2020), the funded projects are developing stations between 800 and 1,600 kilograms per day that will have two to four fueling hoses. As station capacity has grown, the average CEC grant per station has decreased, showing an increasing business case for hydrogen stations. These trends are visible in Figure 4.

Figure 4: Grant Funding and Station Capacity for GFO-15-605 and GFO-19-602



Source: CEC

The CEC used a novel strategy for its most recent hydrogen station solicitation, GFO-19-602. Applicants' projects would progressively deploy stations over time as Clean Transportation Program funding becomes available each year. This approach provides more certainty and clarity about how station development will continue in the coming years so that automakers can better prepare production strategies. The solicitation structure also provides more certainty for station developers, who can now build toward achieving economies of scale and reducing the cost of station equipment.

In addition to CEC-supported infrastructure, developers have begun to plan 23 stations with private funding only. For instance, FirstElement Fuel has included 16 stations in its most recent CEC grant agreement that are being fully funded through private funds, and Iwatani has 7 stations under development without any public support. As the market for hydrogen grows and station developers gain additional experience in deployment, more privately funded stations are likely.

Investments in Medium- and Heavy-Duty Sectors

Under the proposed Clean Transportation Program Investment Plan, the CEC anticipates nearly $100 million in funding for medium- and heavy-duty zero-emission vehicle (ZEV) infrastructure over the next two and a half years from traditional Clean Transportation Program funding sources. With additional funding from the 2021–2022 budget and future ZEV budget proposals in the subsequent two fiscal years, CEC staff anticipates up to $672 million toward medium- and heavy-duty (MD/HD) infrastructure. Some of these funds will involve close coordination with the California Air Resources Board (CARB) for vehicle deployments, while others will be infrastructure-only funding opportunities.

Early Investments in Demonstration Projects

Early in the Clean Transportation Program, between 2014 and 2018, the CEC released four solicitations for advanced freight vehicle and infrastructure demonstration projects. These solicitations awarded more than $90 million to roughly 20 projects demonstrating advanced technology vehicles and infrastructure in the Ports of Los Angeles, Long Beach, and San Diego. These projects deployed several zero- and near-zero-emission MD/HD vehicles, including yard trucks, drayage trucks, gantry cranes, top handlers, and forklifts. The funds also supported the installation of charging and refueling infrastructure for electric and hydrogen vehicles.

These demonstration investments have led to numerous successful project outcomes. For instance, in 2014, Transportation Power (TransPower) was awarded $3 million to build five new battery-electric yard tractors and demonstrated them in various locations throughout the Central Valley. The five yard tractors were used in harsh environments and performed better than TransPower had anticipated. The vehicle manufacturer officially created a line of battery electric yard tractors using TransPower’s motive system that were eligible for incentive vouchers through CARB’s Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) program.

Figure 5: Heavy-Duty Electric Yard Tractor (TransPower)

Source: TransPower

In 2016, the port of Long Beach received $9.7 million from the Clean Transportation Program for its zero-emission terminal equipment transition project. It is demonstrating six battery-electric yard tractors and four rubber-tire gantry cranes that were converted from conventional diesel power to all-electric. Despite challenges from the COVID-19 pandemic, this project continues to progress.

Figure 6: Zero-Emissions Terminal Equipment Transitions Project (Port of Long Beach)

Source: Port of Long Beach

As a final example, the program awarded $2.7 million to the City of Gardena's "Zero-Emission Bus Repower" project in 2015 to convert four transit buses from gasoline-electric hybrid to fully zero-emission battery electric buses. The Gardena Municipal Bus Lines demonstrated the buses on routes through disadvantaged communities for 12 months. The electric buses represented an improvement in sustainability and operability over the gasoline-hybrid buses that made up the majority of Gardena's fleet, and Gardena has subsequently continued to pursue electric bus offerings.

Figure 7: Zero-Emission Bus Repower (City of Gardena)

Source: City of Gardena

Prioritizing MD/HD Investments in ZEV Infrastructure Deployment

The CEC progressed from funding demonstration projects to funding deployment and pilot projects in recent years. State policy toward improving public health and addressing the impacts of local air pollution has resulted in a greater focus on MD/HD fleets, which is why the recent investment plans of the Clean Transportation Program reflect a long-term focus on ZEV infrastructure for trucks and buses. This focus will complement CARB's support of zero-emission MD/HD vehicles through a combination of regulations and vehicle incentive projects such as HVIP and the Clean Off-Road Equipment Voucher Incentive Project (CORE).

As mentioned earlier, Assembly Bill 2127 (Ting, Chapter 365, Statutes of 2018) identifies a potential need for 157,000 chargers to support 180,000 MD/HD ZEVs in the state by 2030. To support this need, the CEC recently released three solicitations targeting ZEV infrastructure deployment for the MD/HD sector: one for transit, one for drayage, and a broader MD/HD block grant known as EnergIIZE Commercial Vehicles. These recent solicitations focused on ZEV infrastructure and deployment of the necessary infrastructure needed to support large-scale fleet conversion and deployment.

The drayage grant funding opportunity is an example of cross-agency collaboration. It is the first collaborative funding opportunity between the CEC and CARB to fund the large-scale deployment of zero-emission, Class 8[14] drayage and regional haul trucks. This solicitation resulted in proposed awards of five projects totaling more than $108 million in combined CEC and CARB funding and was oversubscribed by $85 million. The proposed awards will support 30 hydrogen fuel cell and 250 battery-electric trucks, including fueling infrastructure needed for operation. The CEC's proposed $44 million contribution will support zero-emission fueling infrastructure in addition to workforce training and development, while CARB has committed nearly $64 million toward the vehicles.

EnergIIZE is the first-in-the-nation incentive project for MD/HD ZEV infrastructure and will assist in the construction of infrastructure throughout the state to meet recent executive order goals and truck and bus regulations. Funded up to $50 million, the project is administered by CALSTART[15] with the support of equity partner GRID Alternatives, a nonprofit organization that manages clean energy programs in low-income communities.

The funding opportunity for zero-emission transit infrastructure will support the large-scale conversion of transit bus fleets to zero-emission technologies at several transit agencies. The projects proposed for funding reflect a diversity of fuel and vehicle technologies (including battery-electric and hydrogen projects), geography, and transit agency fleet size.

Near-Zero Emission Fuels

Not all vehicles and transportation applications can rapidly transition to zero-emission alternatives. Even for sectors that have already begun a transition to zero-emission technologies, legacy fleets will continue to use liquid or gaseous combustion fuels for years to come. This may be true for some use cases of MD/HD vehicles. Furthermore, waste-based feedstocks are quite low in life-cycle greenhouse gas (GHG) emissions, to the point that CARB's Low Carbon Fuel Standard (LCFS) currently counts some fuel from these sources as a net negative source of GHG emissions.

The Clean Transportation Program support of near-zero emission fuels has evolved over the years from fuels that can be blended with petroleum products (ethanol, biodiesel) toward drop-in alternatives that are not blended, such as renewable diesel or biomethane. Given LCFS credits and similar federal production credits for these fuels, the market for them is strong,

14 *Class 8 Drayage and Regional Haul Trucks* refers to trucks with a GVWR (Gross Vehicle Weight Rating) greater than 33,000 pounds used for port drayage and/or freight/cargo delivery, including waste haulers, dump trucks, and concrete mixers.

15 CALSTART is a nonprofit organization working nationally and internationally with businesses and governments to develop clean, efficient transportation solutions.

and the Clean Transportation Program has expanded to include fuel production projects for zero-emission fuels, such as renewable hydrogen.

The AltAir Paramount Refinery is an example of the Clean Transportation Program funding in renewable diesel. Locating the project within an existing refinery ensured maximum use of existing equipment, greatly simplified permitting, and sustained jobs for experts in operations and maintenance — thereby sustaining the California economy. The CEC funded the expansion of this refinery to increase production capacity of renewable diesel. GHG emissions from the renewable diesel of the project are up to 80 percent lower than from petroleum diesel and nearly 40 percent less than from biodiesel. Moreover, the coproduced renewable jet fuels are estimated to deliver up to an 80 percent reduction in GHG emissions relative to petroleum-derived jet fuel.

Another recent fuel production success story is the California Bioenergy, LLC, Kern Dairy Cluster Biomethane Upgrading Facility (CalBio). For this project, CalBio designed, built, and operates a biomethane upgrading plant that cleans biogas from surrounding dairies in Kern County to produce high-quality renewable natural gas (RNG).[16] This RNG is then injected into the utility, pipeline where it is ultimately used as a transportation fuel in natural gas vehicles. The biogas collected by the project reduces methane, nitrogen oxides, and hydrogen sulfide previously released into the air. Within two years, the RNG will displace roughly 2 million diesel gallon equivalents in California annually. The California Department of Food and Agriculture awarded additional funding from its share of California Climate Investments for the construction of the dairy digesters.

Manufacturing

The CEC, under the Clean Transportation Program, supports the development of ZEV manufacturing and the emerging supply chain. Early in the program, competitive solicitations offered funding opportunities for feasibility studies, design and engineering, performance testing, site analysis, and pilot projects including bench-scale testing, analysis, and assistance in securing building permits. Project eligibility included the manufacture of alternative fuel vehicles, advanced technology vehicles, eligible vehicle components or a combination thereof.

In subsequent solicitations, the focus for funding eligibility transitioned to manufacturing line processing methods, design, engineering, testing and plan specifications, in addition to

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16 Renewable natural gas (RNG) is a pipeline-quality gas that is fully interchangeable with conventional natural gas and thus can be used in natural gas vehicles. RNG is essentially biogas (the gaseous product of the decomposition of organic matter) that has been processed to purity standards. Like conventional natural gas, RNG can be used as a transportation fuel in the form of compressed natural gas (CNG) or liquefied natural gas (LNG). RNG qualifies as an advanced biofuel under the Renewable Fuel Standard.

equipment acquisition and labor costs required to install and test equipment. For the most recent solicitation, released in 2018, eligibility was limited exclusively to the manufacture of ZEVs, ZEV components, and ZEV infrastructure technologies. The funding was split into two manufacturing categories: (1) complete ZEVs and ZEV components and (2) EV supply equipment and hydrogen refueling station equipment.

For 2020 and 2021, despite the impacts of the COVID-19 pandemic, the CEC received no reports of any manufacturing awardees having to suspend operations because of the pandemic, and most were deemed essential businesses by the respective local governments. Many of the CEC's manufacturing partners continued to improve their capability and capacity by 20 percent to 100 percent in some of the key manufacturing areas while adding new production lines and jobs in California. In fact, ZEVs were California's number one export in 2020.

Proterra, Inc., an electric bus manufacturer, opened a new battery production line in City of Industry, California. At capacity, this new manufacturing plant will create dozens of new jobs in Los Angeles County, including more than two dozen positions represented by the United Steelworkers Local 675. Proterra and the charging equipment manufacturer ChargePoint have become publicly traded companies with a combined market capitalization of more than $10 billion. This development sends a strong economic signal that California's ZEV economy will continue to grow and strengthen.

Figure 8: Electric Bus Manufacturing (Proterra)

Source: Proterra, Inc.

Key investments in manufacturing charging equipment have also led to market expansion and the growth of small companies. For example, in 2019, the Clean Transportation Program provided the electric charger company FreeWire with a $2 million grant to scale-up its manufacturing. FreeWire’s chargers have onboard energy storage, reducing installation costs and install time, lowering charging costs, and providing charging services during power outages. In 2020, the company saw an investment of $25 million in venture capital. Then, in early 2021, FreeWire saw an additional $50 million in investment. Clean Transportation Program support provides opportunities for emerging companies to grow and secure private investment, contributing to the growth of the state’s economy and ZEV leadership.

Workforce Training and Development

Clean Transportation Program investments into workforce training and development are central to the advancement of clean transportation technologies in commercial markets. To date, the CEC has invested more than $35 million into workforce projects benefitting more than 20,000 trainees.

Early in the program, the CEC entered into interagency agreements with other state entities with workforce training experience, such as the Employment Development Department, Employment Training Panel, California Community College Chancellor’s Office, and California Workforce Development Board. As the program matured, the CEC developed additional agreements directly with community colleges. The partnership with community colleges includes:

- ZEV Curricula — College faculty developed ZEV curricula for degrees, credit, and certificates at their colleges for ZEV technology for light-duty-vehicle and truck/bus platforms. A new training project focuses on ZEV curricula in community colleges serving students in disadvantaged communities and low-income populations.
- Electric School Bus Training Project — The CEC awarded funding to school districts to replace diesel school buses with electric school buses in 2019. School districts will receive customized training from nearby experienced community college faculty on these buses for maintenance/service technician staff and school bus operators.
- ZEV High School Pilot Career Opportunity Project — In 2018, Advanced Transportation and Logistics (ATL), led by Cerritos Community College, developed a pilot training

project for high school automotive programs. The project builds on existing high school automotive programs and increases awareness for the state's high school students in clean transportation careers. Twenty-seven high schools have been awarded funds to establish "Auto 3: ZEV Technology" technical training programs that have a career pathway to programs offered at California community colleges.

These projects have already provided a significant return on investment, especially in underserved communities where schools are located. As an example, for the high school project, early results show more than 1,800 students have enrolled in these programs and more than 36 faculty have been trained in ZEV technology. These results are critical as ZEV employers are partners and offer immediate job employment opportunities with sustainable wages.

The California Conservation Corps (CCC) is another recent workforce development partner. The agreement with CCC will result in corps members being trained to install and maintain EV charging stations while working with electrical contractors to develop skills needed to enter apprenticeship programs.

The CEC is preparing to release an upcoming Inclusion, Diversity, Equity, Access, and Local (IDEAL) ZEV workforce pilot solicitation as the next step in its workforce investment. The IDEAL ZEV workforce pilot focuses investments on ZEV training and skills development, supports community-based training and career transportation pathway development, intentionally includes and expands training to frontline equity and tribal communities and requires an explicit connection between training and employment.

CHAPTER 3: Quantifying the Benefits of the Clean Transportation Program

The statutes of the Clean Transportation Program establish a benefits report requirement for the program as part of each biennial *Integrated Energy Policy Report (IEPR)*. This evaluation must include the expected benefits such as the contribution toward improving air quality and reducing petroleum use and greenhouse gas (GHG) emissions. The report must also include market transformation benefits for the transition to a diverse portfolio of clean, alternative transportation fuels. While market transformation benefits can be difficult to quantify, it is crucial that the state push toward a zero-emission market transformation to meet state goals and reduce the costs of the climate crisis, wildfires, and droughts.

The California Energy Commission (CEC) contracted with the National Renewable Energy Laboratory (NREL) to develop methods for calculating the expected benefits from projects funded from the inception of the program through March 2021 and projected those benefits to 2030. Quantification of the benefits of Clean Transportation Program investments is subject to continuing improvement and refinement. Table 4 shows the amount of Clean Transportation Program funding included in NREL's 2021 analysis by project type, as well as the corresponding percentage of all program investments within that project type. The percentage of program investments analyzed by NREL is less than 100 percent in situations where certain projects attributes don't align with NREL's analytical methods, or where projects were partly funded but not completed.

Table 4: Clean Transportation Program Funding Analyzed by NREL by Project Type Through August 2021

Project Type	Clean Transportation Program Funding Analyzed by NREL (in millions)	Percent of All Clean Transportation Program Investments
Biomethane Production	$65.4	96
Gasoline Substitutes Production	$23.0	85
Diesel Substitute Production	$56.8	89
Electric Vehicle Charging	$192.6	100
Hydrogen Refueling Stations	$137.0	82
E85 Fueling Stations	$3.6	100
Upstream Biodiesel Infrastructure	$1.98	50
Natural Gas Fueling Stations	$21.5	89
Natural Gas Commercial Trucks	$72.6	84
Light-duty battery-electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs)	$3.4	100
Clean Vehicle Rebate Project (CVRP) and Hybrid and Zero-	$28.5	100

Project Type	Clean Transportation Program Funding Analyzed by NREL (in millions)	Percent of All Clean Transportation Program Investments
Emission Truck and Bus Voucher Incentive Project (HVIP) Support		
Medium- and Heavy-Duty (MD/HD) Truck Demonstration	$119.1	95
Manufacturing	$34.0	61
Other (inc. workforce training; standards development; regional readiness plans)	$0.0	0
Total	**$759.48**	**84**

Source: NREL, CEC

For this 2021 Benefits Report, NREL used the same approach toward quantifying Clean Transportation Program project benefits as it has in previous years, beginning with the *2014 IEPR Update*.[17] This quantification includes analyzing two categories of benefits: expected benefits and market transformation benefits. *Expected benefits* consist of the estimated direct benefits from the CEC-funded project. These expected benefits are directly correlated with the amount of usage of a project (such as millions of gallons of fuel produced, kilowatt-hours dispensed, or electric miles traveled). In contrast, *market transformation benefits* consist of the estimated indirect benefits from funded projects; more description is provided in the "Market Transformation Benefits" section below.

Within expected benefits and market transformation benefits, NREL assesses the impacts of projects on petroleum use reduction, GHG emissions reduction, and air quality benefits.

Staff emphasizes that the benefits assessed in NREL's analysis reflect the benefits from projects that the Clean Transportation Program has at least partially funded. However, project developers, their investors, and other public programs contribute varying levels of funding to a project supported by the Clean Transportation Program. Thus, this assessment can present a big picture view of the total benefits that the Clean Transportation Program has supported, but it does not claim attribution of those benefits to the program itself. For example, credits that fuel producers earn from the Low Carbon Fuel Standard (LCFS) contribute a great deal to a project developer's decision to move forward on a project, so some of the benefits could also arguably accrue to the LCFS. The benefits report, however, does not attribute benefits across

17 C. Neuman, M. Gilleran, C. Hunter, R. Desai, and A.F.T. Avelino. (National Renewable Energy Laboratory). 2021. *Program Benefits Guidance Update: Analysis of Benefits Associated With Projects and Technologies Supported by the Clean Transportation Program*. California Energy Commission. Publication Number: CEC-600-2021-039. https://efiling.energy.ca.gov/GetDocument.aspx?tn=240837&DocumentContentId=74672.

different program and market factors; rather, it represents an accounting of the benefits associated with supported projects. For this reason, when reviewing the estimated benefits from different project types alongside one another (or other programs or investments), the reviewer should be aware that the inputs, assumptions, and methods may not allow appropriate comparisons.

Expected Benefits

Expected benefits represent the outcomes estimated to be directly supported by Clean Transportation Program funding, shown in Tables 5 and 6. These benefits are based on the calculated displacement of petroleum-derived fuels for the vehicle, fuel, or infrastructure. To estimate GHG benefits, additional calculations consider the carbon intensity of a fuel. For example, the carbon intensity of biodiesel production depends in part on the feedstock input at a funded facility; similarly, the carbon intensity of an electric vehicle (EV) charger depends on the resource mix of the electricity grid in a given year. Air quality calculations consider baseline petroleum pollution emissions against the reduced pollutant profile of a replacement fuel. For example, hydrogen fuel used in light-duty fuel cell EVs have no oxides of nitrogen (NO_x) or tailpipe particulate matter (PM) emissions compared to the petroleum it displaces.

Key methodological steps for the calculations vary by category. For fuel production, the analysis assumes that fuel production numbers are those reported by the agreement, whether in the forward-looking scope of work of the project or, if a project was completed, the verified resulting outputs. From the amount of fuel produced, GHG emissions reductions can be determined based the GHG emissions of the alternative fuel compared to the GHG for the corresponding fossil fuel.

For fueling infrastructure projects, the key assumptions vary by fuel type. Because combustion fuels generally move into a large existing market with fairly reliable consumption, the reported refueling throughput provides for relatively reliable petroleum substitution and subsequent benefits analysis.

The more challenging fueling infrastructure types to account for are hydrogen refueling stations and electric charging infrastructure. Although the displacement of petroleum for these fuels is relatively straightforward on a per-kilogram or per-kilowatt-hour basis, the energy supplied per station or charger is subject to more uncertainty, requiring additional assumptions.[18] For instance, although the zero-emission vehicle (ZEV) market is widely expected to grow rapidly over the next few years (and decades), there is more uncertainty about how much usage to assign to refueling stations and chargers.

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18 Additional discussion of caveats and sensitivities occurs in the "Key Sensitivities" discussion below.

Within NREL's analysis, hydrogen refueling stations are assigned station refueling output of 45 percent of maximum capacity, with a three-year ramping period. This assumption is based on historical data from existing stations.

Electric vehicle chargers have a much broader geographical distribution, and the Clean Transportation Program will be supporting the installation of tens of thousands of them. To inform the average outputs across various charger types, CEC and NREL staff used historical data to model usage patterns by charger category (for example, multifamily housing, workplace, public, and DCFC) using the CEC's EVI-Pro 2 infrastructure assessment model. Using EVI-Pro 2 allows for assumptions that are generally in agreement with the modeling approach used in the aforementioned AB 2127 report. As shown in Table 5, by 2030, the expected annual benefits for commercial-scale projects from Clean Transportation Program investments are 261 million gallons of petroleum reduction and 3 million metric tons[19] of GHG reduction.

Table 5: Annual Petroleum Fuel and GHG Reductions (Expected Benefits)

Project Type	Petroleum Fuel Reductions (in million gallons)			GHG Reductions (in thousand tons carbon dioxide equivalent [$CO2_e$])		
	2020	2025	2030	2020	2025	2030
Fuel Production- Biomethane	1.6	11.6	12.0	25.5	250.8	264.4
Fuel Production- Diesel Substitutes	23.3	56.9	56.9	241.8	927.8	927.9
Fuel Production- Gasoline Substitutes*	5.5	12.9	13.2	18.2	99.4	102.8
Fueling Infrastructure- Biodiesel	6.0	6.0	6.0	81.0	81.0	81.0
Fueling Infrastructure- E85	5.9	6.0	6.0	17.8	18.1	18.1
Fueling Infrastructure- Electric Chargers	3.5	29.4	49.0	33.3	285.2	499.0
Fueling Infrastructure- Hydrogen	2.8	20.1	28.6	21.5	166.1	237.2
Fueling Infrastructure- Natural / Renewable Gas	24.5	25.5	25.5	86.2	88.9	88.9
Vehicles- CVRP and HVIP Support	1.8	1.4	0.7	18.1	13.6	6.7

19 A unit of weight equal to 1,000 kilograms (2,205 pounds).

Project Type	Petroleum Fuel Reductions (in million gallons)			GHG Reductions (in thousand tons carbon dioxide equivalent [CO2e])		
Vehicles- MD/HD Truck Demonstration	0.9	1.5	1.0	7.9	12.0	8.8
Vehicles- Light Duty BEVs and PHEVs**	0.0	0.0	0.0	0.2	0.5	0.2
Vehicles- Liquefied Petroleum Gas (LPG) Commercial Trucks	0.2	0.2		0.6	0.5	
Vehicles- Natural Gas Commercial Trucks	3.9	4.7	2.0	4.0	3.2	-0.1
Total	**80.1**	**176.1**	**200.8**	**556.1**	**1947.0**	**2,235.1**

Source: NREL. Subtotals and totals may not match due to rounding. *Does not include pre-2020 benefits from projects funded under the California Ethanol Producers Incentive Program.

Key takeaways from Table 5 include the following:

- The benefits of electric chargers ramp up over time because of increasing plug-in electric vehicles (PEVs) on the road, increasing expected charger utilization, and decreasing electricity GHG emissions.
- Benefits from commercial-scale fuel production projects funded by the Clean Transportation Program show large GHG reductions through 2030, but GHG reductions from ZEV technologies will still be necessary to meet 2030 and later targets.

In its expected benefits analysis, NREL also included tailpipe reductions of certain key criteria pollutants: NO_x and $PM_{2.5}$.[20] However, for this analysis, NREL focused specifically on fuel and vehicle types with emission reductions recognized under the VISION and GREET models.[21] This focus narrows the analysis to projects using electricity and hydrogen as the alternative fuel. Table 6 summarizes the annual NO_x and $PM_{2.5}$ reductions anticipated from the expected benefits approach.

20 *$PM_{2.5}$* refers to fine inhalable particles that are generally 2.5 micrometers or smaller.

21 The *VISION* model was developed by Argonne National Laboratory to provide estimates of the possible energy and oil use and carbon emission impacts of advanced vehicle technologies and alternative fuels through 2100. More information on the VISION model is available at https://www.anl.gov/es/vision-model. The *GREET* model provides a full life-cycle model that looks at energy and emissions impacts of new and advanced transportation fuels. More information on the GREET model is available on the Argonne National Laboratory's webpage at https://greet.es.anl.gov/greet.models.

Table 6: Annual Air Pollutant Reductions (Expected Benefits)

Project Type	NO_x Reductions (Tonnes/ year)	NO_x Reductions (Tonnes/ year)	NO_x Reductions (Tonnes/ year)	$PM_{2.5}$ Reductions (Tonnes/ Year)	$PM_{2.5}$ Reductions (Tonnes/ Year)	$PM_{2.5}$ Reductions (Tonnes/ Year)
	2020	**2025**	**2030**	**2020**	**2025**	**2030**
Fuel Infrastructure-Electric Chargers	2.00	11.70	26.38	27.82	27.82	27.82
Fuel Infrastructure-Hydrogen	1.92	11.93	17.07	18.46	18.46	18.46
Fuel Infrastructure-Natural Gas	N/A	N/A	N/A	N/A	N/A	N/A
Vehicles- CEC Support for CVRP/HVIP*	7.03	6.41	1.34	1.43	1.43	1.43
Vehicles- Light-Duty BEVs and PHEVs	0.03	0.06	0.03	0.03	0.03	0.03
Vehicles- LPG Commercial Trucks	1.49	1.55	-	-	-	-
Vehicles- NG Commercial Trucks	42.72	56.95	23.26	-	-	-
Vehicles-Demonstration	8.23	15.70	12.23	2.42	2.42	2.42
Total	**63.42**	**104.30**	**80.31**	**50.16**	**50.16**	**50.16**

Source: NREL *The Clean Transportation Program previously provided funding to supplement the CVRP and HVIP. This funding represents only a small share of the California Air Resources Board's (CARB's) overall CVRP and HVIP investment.

Key takeaways from Table 6 include the following:

- Certain combustion fuel alternatives (such as gasoline substitutes, diesel substitutes) do not have air quality benefits that are discernable from existing fuel, so there is no reliable way of assigning distinct benefits.
- In contrast, because PEVs and fuel cell electric vehicles (FCEVs) eliminate the combustion processes, they have clear air quality benefits.
- Natural gas trucks offer the potential for NO_x emissions, but (per the preceding table) do not offer comparable GHG emissions reduction potential.

Market Transformation Benefits

Market transformation benefits represent a range of future investments enabled or supported by the funding portfolio of the program. For example, the continuing market expansion of BEVs and PEVs will be partially supported by current Clean Transportation Program investments into electric charging infrastructure and the manufacture of battery and electric drivetrain technology. For electric chargers, charging availability is a leading consumer concern for vehicle adoption, so additional electric chargers contribute to changing consumer perceptions about the ease of purchasing a PEV. Similarly, the effect of a successful demonstration of an advanced technology truck or novel fuel production process increases the likelihood of that technology achieving future commercial success.

Market transformation analysis requires several assumptions about consumer behavior, future markets, and business responsiveness. In this regard, the market transformation benefits have more uncertainty than the expected benefits. However, market transformation benefits are critical to understanding the benefits of the Clean Transportation Program, and the associated higher level of uncertainty is not a reason to disregard them.

Because of this uncertainty, NREL incorporates various assumptions into a "low case" and "high case" for market transformation benefits. Low cases reflect conservative assumptions about demand elasticity for ZEVs, savings from economies of scale, and the ability of successful demonstration projects to leverage private interest for larger commercial-scale projects. High cases reflect optimistic assumptions. The low and high case market transformation results help define a range of reasonable results.

NREL has identified four potential ways Clean Transportation Program projects can influence market transformation. These potential influences are described in Table 7. There may be additional ways that Clean Transportation Program projects influence the future market growth of clean fuels and vehicles; however, these examples are what NREL found to be the most readily quantifiable. The methods used to quantify these influences are described more fully in NREL's 2021 *Analysis of Benefits Associated With Projects and Technologies Supported by the Clean Transportation Program,*[22] and were first described in program benefits guidance provided by NREL in 2014.[23]

22 C. Neuman, M. Gilleran, C. Hunter, R. Desai, and A.F.T. Avelino. (National Renewable Energy Laboratory). 2021. *Program Benefits Guidance Update: Analysis of Benefits Associated With Projects and Technologies Supported by the Clean Transportation Program.* California Energy Commission. Publication Number: CEC-600-2021-039. https://efiling.energy.ca.gov/GetDocument.aspx?tn=240837&DocumentContentId=74672.

23 NREL. 2014. *Analysis of Benefits Associated With Projects and Technologies Supported by the Alternative and Renewable Fuel and Vehicle Technology Program.* https://efiling.energy.ca.gov/GetDocument.aspx?tn=73185.

Table 7: Market Transformation Benefits Description

Market Transformation Influence	Applicable Clean Transportation Program Project Types	Description of Influence Outcomes
Perceived Vehicle Price Reduction	Electric charging Hydrogen stations Light-duty BEVs and PHEV incentives	-Increased consumer awareness -Removal of consumer choice barriers via increased refueling access
Vehicle Cost Reduction	Manufacturing	-Reduced cost to produce or supply a technology -"Learn by doing" -Economies of scale in production
Next-Generation Trucks	MD/HD truck demonstration Medium-Duty BEV incentives	-Additional trucks deployed as a result of successful demonstration projects
Next-Generation Fuels	Biofuel production (all fuel types)	-Additional or expanded biofuel production facilities in response to successful projects

Source: NREL

Table 8 summarizes the total market transformation benefits from Clean Transportation Program projects in terms of petroleum displacement, GHG emissions reduction, and air pollutant reduction. Since market transformation benefits follow the direct expected benefits of a project, this table focuses on benefits in 2030. As with the expected benefits, NREL does not attempt to quantify air pollutant reductions associated with the market transformation benefits of biofuel production projects (under "Next-Generation Fuels").

Table 8: Annual Market Transformation Benefits in 2030

Market Transformation Influence[24]	Case	Petroleum Displacement (million gallons)	GHG Reduction (thousand tonnes CO2e)	NOx Reduction (tonnes)	$PM_{2.5}$ Reduction (tonnes)
		2030	**2030**	**2030**	**2030**
Perceived Vehicle Price Reductions, Electric Charging, Hydrogen Stations, Light-Duty BEVs and PHEV Incentives	**High**	65.3	803.0	69.2	3.3

24 See Table 7 for descriptions of each type of market transformation influence.

Market Transformation Influence[24]	Case	Petroleum Displacement (million gallons)	GHG Reduction (thousand tonnes CO2e)	NOx Reduction (tonnes)	$PM_{2.5}$ Reduction (tonnes)
Perceived Vehicle Price Reductions, Electric Charging, Hydrogen Stations, Light-Duty BEVs and PHEV Incentives	**Low**	24.3	296.1	26.0	1.3
Vehicle Cost Reduction, Manufacturing	**High**	146.2	2367.4	790.6	34.7
Vehicle Cost Reduction, Manufacturing	**Low**	59.7	1,392.6	699.0	30.0
Next-Generation Trucks, MD/HD Truck Demonstration, MD BEV Incentives	**High**	290.8	1,825.7	3,526.3	25.3
Next-Generation Trucks, MD/HD Truck Demonstration, MD BEV Incentives	**Low**	19.0	185.1	230.4	1.7
Next-Generation Fuels, Biofuel Production	**High**	169.2	1,234.5	N/A	N/A
Next-Generation Fuels, Biofuel Production	**Low**	42.3	308.6	N/A	N/A
	Total High	**671.5**	**6,230.6**	**4,386.1**	**63.4**
	Total Low	**145.3**	**2,182.4**	**955.4**	**32.9**

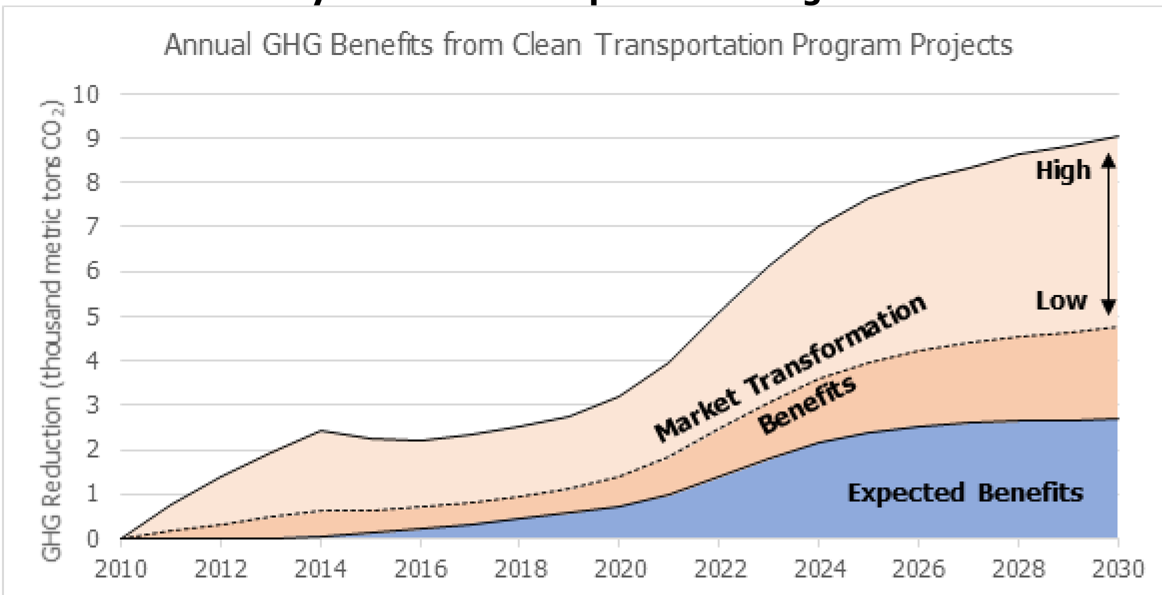
Source: NREL

Key takeaways from Table 8 include the following:

- Large ranges between high and low reflect significant variability in market conditions and project outcomes.
- Next-generation trucks show significant market transformation potential to reduce criteria emissions (NO_x and $PM_{2.5}$).

Finally, Figure 9 below depicts the combined expected and market transformation benefits from Clean Transportation Program-funded projects in reducing GHG emissions each year through 2030.

Figure 9: Annual GHG Emissions Reduction From Fuel Production Projects Funded by the Clean Transportation Program



Source: NREL, CEC staff

Key Sensitivities

For the expected benefits and market transformation benefits, it is important to highlight key sensitivities and assumptions that affect the benefits results. This emphasis is especially important for new fueling infrastructure such as hydrogen and electric charging. Fuel production of biofuels is simple to measure, and the fuel usually quickly and reliably enters the fuel market. In contrast, hydrogen and charging infrastructure usage (and hence benefits) may vary according to changing driver behavior and evolving vehicle markets. While these can be harder to quantify, they are necessary technologies to meet state goals.

For the expected benefits of hydrogen fueling infrastructure, NREL used a three-year ramp rate and 45 percent output plateau for expected fueling of FCEVs. The 45 percent output plateau is based on current station outputs. For example, a station capable of dispensing 1,000 kilograms of hydrogen per day would be expected to, on average, dispense 450 kg per day once it reaches the plateau. Similarly, low sales of FCEVs may result in lower fuel consumption per station even if the state meets its goals for hydrogen station deployment.

The charging infrastructure analysis used current documented charger usage rates and the CEC/NREL EVI-Pro 2 modeling tool to ramp up per-charger usage as more plug-in electric vehicles begin operation. Furthermore, many of the chargers expected to result from encumbered Clean Transportation Program funds have not yet been installed. Improved siting of those upcoming chargers could result in much higher usage than currently expected, which could increase the benefits from these installations. However, focusing on usage alone may result in an underinvestment in low-income or disadvantaged communities if they are slower to adopt ZEVs. An appropriate balance must be struck to ensure that the state meets the ZEV infrastructure needs of all California communities.

Market transformation benefits also have key sensitivities. For example, perceived vehicle price reductions and consumer behavior in response may be quite different. In the case of ZEVs, several market analysts predict that prices for BEVs will continue to decrease substantially over the next few years, reaching price parity with comparable internal combustion vehicles around 2025 or sooner and costing less than a combustion vehicle afterward. If this price parity occurs, consumer responsiveness to the perceived benefit of reliable charging infrastructure may be stronger than even the high case predicts.

Benefit-Cost Assessment

As part of the biennial evaluation of the program, Health and Safety Code Section 44273 also requires the CEC to include a "benefit-cost assessment" for Clean Transportation Program funded projects. While such an assessment is not further defined, a reasonable assumption is that "benefit-cost" has a meaning similar to that used elsewhere in the clean transportation statutes. Specifically, the "benefit-cost" represents the "… expected or potential greenhouse gas emissions reduction per dollar awarded by the commission …"[25]

Unlike the previous estimates of benefits, this estimate requires assessing GHG emissions reductions on a cumulative basis, not an annual one. A simple yet conservative assumption is to use the cumulative GHG emission reductions of Clean Transportation Program-funded projects through 2030. This is because the dollar value is available up to 2021, and all projects are assumed to accrue benefits beyond that time. Based on this approach, the cumulative GHG emission reductions of expected benefits and market transformation benefits by 2030 range from roughly 42.8 million metric tons (using the low case for market transformation benefits) to 81.8 million metric tons (using the high case).

The CEC has awarded nearly $760 million toward Clean Transportation Program projects (not including canceled and defunded projects) with measurable GHG emission reductions using the method presented in this report. When including projects that do not readily lend themselves to measurable GHG emissions (such as regional fuel readiness grants, workforce training agreements, and fuel standards and certification agreements), this amount increases to just over $1 billion. Table 9 shows the resulting benefit-cost ratios, depending on (1) which funding amount is used as the cost and (2) whether the low case or the high case for market transformation benefits is applied. The values in Table 9 represent the approximate amount of carbon dioxide-equivalent metric tons reduced for every $1 invested by the Clean Transportation Program. Table 10 presents the equivalent calculation in dollars per metric ton.

25 Health and Safety Code Section 44270.3.

Table 9: Kilograms CO_2e Reduced Through 2030 per Clean Transportation Program Dollar

	Cost Basis: Analyzed Projects Only	Cost Basis: All Projects
Expected Benefits + Market Transformation (Low Case)	56.3 kg per $	40.8 kg per $
Expected Benefits + Market Transformation (High Case)	107.7 kg per $	78.0 kg per $

Source: CEC

Table 10: Clean Transportation Funding per Metric Ton CO_2e Reduced Through 2030

	Cost Basis: Analyzed Projects Only	Cost Basis: All Projects
Expected Benefits + Market Transformation (Low Case)	$17.8 per metric ton	$24.5 per metric ton
Expected Benefits + Market Transformation (High Case)	$9.3 per metric ton	$12.8 per metric ton

Source: CEC

Other Benefits

Beyond the reporting metrics established in program statutes, NREL conducted a benefits analysis of the Clean Transportation Program in terms of equity. Using the expected benefits of projects, NREL assigned benefits to different geographic regions across the state. For heavy-duty trucks and the alternative fuels used for them, NREL assigned benefits according to overall average truck traffic across the state, with heavily trafficked corridors receiving more benefits. For light-duty ZEV infrastructure (including electric chargers and hydrogen refueling stations), NREL assigned benefits to the census tract of the project location.

Using this method, communities designated as disadvantaged (according to CalEnviroScreen 3.0) received a greater proportion of Clean Transportation Program benefits, displayed in Table 11. While benefits in disadvantaged communities appear lower in some cases than those in all other communities, it is important to be aware that residents in disadvantaged communities represent only about 25 percent of the state's population. When weighted by population, residents in disadvantaged communities receive about three times greater NO_x reduction and $PM_{2.5}$ reduction benefits relative to residents outside disadvantaged communities. A similar pattern is evident in Table 12, which displays the distribution of benefits in low-income communities; in this case, residents in low-income communities receive about twice the NO_x reductions and $PM_{2.5}$ reductions on a per capita basis. With a greater emphasis on equity in funding moving forward, CEC staff anticipates that residents of disadvantaged and low-income communities can (and should) receive an even greater share of these direct air quality benefits in the future, aligning with the state's environmental justice goals.

Table 11: Benefits to Disadvantaged Communities

	Benefits in Disadvantaged Communities	Benefits Outside Disadvantaged Communities	Benefits Per Million Residents in Disadvantaged Communities	Benefits Per Million Residents Outside Disadvantaged Communities
Petroleum Reduction (million gallons)	52.81	86.2	5.6	3.1
GHG Reduction (thousand metric tons)	580.01	872.84	62.0	31.3
NO_x Reduction (metric tons)	376.7	340.42	40.3	12.2
$PM_{2.5}$ Reduction (metric tons)	14.9	13.65	1.6	0.5

Source: NREL, CEC

Table 12: Benefits to Low-Income Communities

	Benefits in Low-Income Communities	Benefits Outside Low-Income Communities	Benefits Per Million Residents in Low-Income Communities	Benefits Per Million Residents Outside Low-Income Communities
Petroleum Reduction (million gallons)	90.24	48.76	4.3	3.0
GHG Reduction (thousand metric tons)	958.14	494.61	45.8	30.3
NO_x Reduction (metric tons)	521.1	195.93	24.9	12.0
$PM_{2.5}$ Reduction (metric tons)	20.7	7.85	1.0	0.5

Source: CalEnviroScreen 3.0, NREL, CEC

CHAPTER 4: Key Findings and Conclusions

The projects funded by the Clean Transportation Program have recently shifted more toward zero-emission technologies and fuels. These options lend themselves to a clean transportation future by contributing more to cleaner air, and they have the greatest potential for reduced absolute greenhouse gas (GHG) emissions. By supporting new combustion-free options, zero-emission fuels also have the greatest potential for reducing petroleum dependency. Finally, the greatest potential for fuel cost savings and reduced vehicle maintenance costs come from zero-emission technologies, which will have the greatest long-term economic benefit.

Some obstacles and challenges to meeting the goals of clean air, GHG emissions reduction, and reduced petroleum dependence remain. Lessons learned from the zero-emission projects funded by the Clean Transportation Program show that there is a need to increase access to zero-emission vehicle (ZEV) refueling for all Californians and fully consider ZEVs as interactive parts of a broader clean energy landscape. These needs can be achieved by market scaling, streamlining administrative processes for installation, standardizing fueling equipment, supporting needs in equity communities, and developing innovative policies to address the evolving needs in this new and promising sector.

Recommendations for furthering the goals of the Clean Transportation Program include the following:

- Prioritize technologies with the greatest market potential for transportation sector growth and broader economic benefit.
- Continue to prioritize equity and clean transportation access for all Californians and ensure maximum benefit to communities most impacted by transportation-related air quality impacts.
- Support projects and technologies that contribute to a simple and seamless consumer vehicle refueling experience.
- Support projects that have the greatest potential for reducing refueling infrastructure costs.