South Coast
Air Quality
Management District

Clean Fuels Program

2023 Annual Report & 2024 Plan Update

Technology Advancement Office

Leading the way to cleaner air

Cover Photo Credits

Clockwise:

- Volvo Class 8 VNR Electric deployed at NFI Ontario site for JETSI Pilot Project
- Daimler Class 8 eCascadia deployed at Schneider South El Monte site for JETSI Pilot Project
- NFI BET maintenance facility in Ontario for JETSI Pilot Project
- Schneider 350 kW DC fast chargers to support 92 battery electric trucks at South El Monte site
- New Flyer XHE40 Xcelsior fuel cell bus deployed at SunLine Transit serving Coachella Valley

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EXECUTIVE SUMMARY

Introduction

South Coast Air Quality Management District (South Coast AQMD) is the air pollution control agency for Orange County and the urban portions of Los Angeles, Riverside and San Bernardino counties. This region, which encompasses the South Coast Air Basin (Basin) as well as small portions of the Mojave Desert and Salton Sea Air Basins, historically experiences the worst air quality in the nation due to the natural geographic and atmospheric conditions of the region, coupled with the high population density and associated mobile and stationary source emissions.

In 1988, Senate Bill (SB) 2297 (Rosenthal) was signed into law (Chapter 1546). It initially established a five-year program to increase the use of clean fuels, but subsequent legislation extended and removed the sunset clause for the Program. That legislation also reaffirmed the existence of the Technology Advancement Office (TAO) to administer the Clean Fuels Program. The Clean Fuels Program is an integral part of South Coast AQMD's effort to achieve the significant nitrogen oxides (NOx) emission reductions called for in the 2022 Air Quality Management Plan (AQMP) because it affords South Coast AQMD the ability to fund research, development, demonstration and accelerated deployment of clean fuels and transformative transportation technologies.

Using funding from a $1 motor vehicle registration fee, the Clean Fuels Program encourages, fosters and supports clean fuels and transportation technologies, such as hydrogen fuel cells, advanced natural gas (NG) technologies, alternative fuel engines, battery electric vehicles, plug-in hybrid electric vehicles and related fueling infrastructure including renewable fuels. A key strategy of the Program is its public-private partnerships with private industry, technology developers, academic institutions, research institutions, and government agencies. Since 1988, the Clean Fuels Program leveraged nearly $267.9 million into $1.7 billion in clean technology projects. Leveraging of the Clean Fuels Fund is based on executed contracts and total project costs from the prior year's Clean Fuels Annual Report and Plan Update. The Mobile Source Air Pollution Reduction Review Committee (MSRC) discretionary fund, established under Assembly Bill 2766, is another source of funding for mobile source emission reduction projects. The MSRC develops an annual Work Program to define the categories of projects for funding. Each year, approximately $15 million, collected from motor vehicle registration fees, is allocated to the discretionary fund and is an important source of funding to supplement the Clean Fuels program.

As technologies are commercialized (battery electric trucks or BETs) or move towards commercialization (fuel cell trucks or FCTs), the Clean Fuels Program partners with large original equipment manufacturers (OEMs), such as Daimler, Volvo, Hyundai and Peterbilt to deploy these vehicles at scale. These OEM partnerships allow the Program to leverage their research, product development, customer relationships, and financial resources needed to move advanced technologies from the laboratories to the field and into customers' hands. The OEMs have the resources and capabilities to design, engineer, test, manufacture, market, distribute and service quality products under brand names that are trusted. This is the type of scale needed to achieve emission reductions to attain national ambient air quality standards (NAAQS).

South Coast AQMD plays a leadership role in technology development and commercialization, along with its partners, to accelerate criteria pollutant and greenhouse gas (GHG) reductions. The Clean Fuels Program has traditionally supported a portfolio of technologies at different technology readiness levels. This helps

with the development of new technologies across many different mobile sectors in need of new technologies that provide emission and GHG reductions and health benefits. This approach enhances the region's chances of achieving the NAAQS.

California Health and Safety Code (H&SC) 40448.5(e) calls for the Clean Fuels Program to consider factors such as: current and projected economic costs and availability of fuels; cost-effectiveness of emission reductions associated with clean fuels compared with other pollution control alternatives; use of new pollution control technologies in conjunction with traditional fuels as an alternative means of reducing emissions; potential effects on public health, ambient air quality, visibility within the region; and other factors. The Legislature recognized the need for flexibility, allowing focus on a broad range of technology areas, including cleaner fuels, vehicles, equipment, and infrastructure, which helps South Coast AQMD make progress toward achieving its clean air goals.

California H&SC 40448.5.1 requires South Coast AQMD to prepare and submit a Clean Fuels Annual Report and Plan Update annually to the Legislative Analyst by March 31. The Clean Fuels Annual Report looks at Program accomplishments in the prior calendar year (CY) and Clean Fuels Plan Update looks ahead at proposed projects for the next CY, re-calibrating technical emphasis of the Program.

Deploying charging infrastructure for Class 8 heavy-duty (HD) BETs for the Joint Electric Truck Scaling Initiative (JETSI) Pilot Project required significant effort. Schneider successfully deployed sixteen 350 kW DC fast chargers to support its 50 Daimler Class 8 BETs in June 2023. NFI deployed temporary power charging in January 2024 and will complete permanent power charging in August 2024. Solar and battery storage will be deployed by December 2024 to offset demand charges at NFI's Ontario site. Due to utility requirements and regulations, delays in obtaining electrical switch gear along with increased costs, the NFI supporting charging infrastructure is behind schedule. The NFI infrastructure installation is providing valuable experience in helping identify the challenges and costs that widespread truck charger infrastructure installations may encounter.

Setting the Stage

The overall strategy of the Clean Fuels Program is largely based on emission reduction technologies identified in the 2022 AQMP and South Coast AQMD Board directives to protect the health of almost 18 million residents (nearly half the population of California) in the Basin. The 2022 AQMP is the long-term regional blueprint that identifies the fair-share emission reductions from all jurisdictional levels (e.g., federal, state and local). The 2022 AQMP is composed of stationary and mobile source emission reductions from traditional regulatory control measures, incentive-based programs, projected co-benefits from climate change programs, mobile source strategies and other innovative approaches, including indirect source measures and incentive programs, to reduce emissions from federally regulated sources (e.g., aircraft, locomotives and ocean-going vessels). California Air Resources Board's (CARB) 2022 State Implementation Plan (SIP) Strategy included a revised mobile source strategy required for the Basin to meet the 2015 8-hour ozone standard of 70 ppb by 2037. The CARB 2022 SIP Strategy for both mobile and stationary sources require rapid deployment of zero emission technologies to achieve air quality targets.

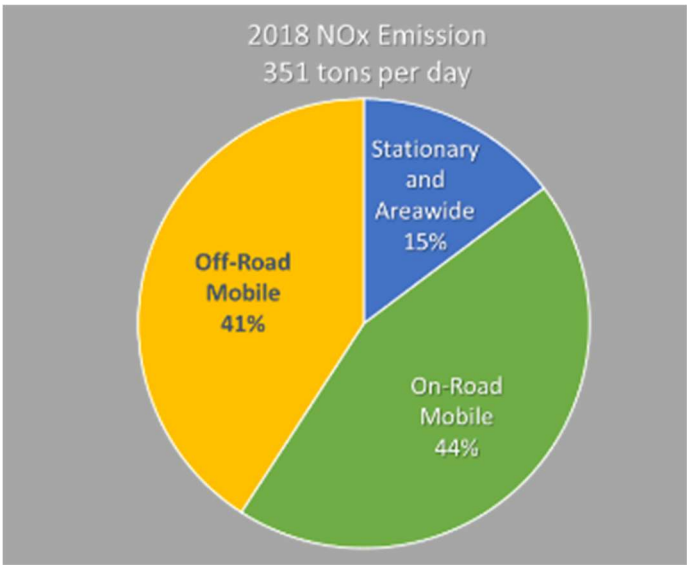


Figure 1: NOx Emissions by Source Category in South Coast Basin for 2018

Ground level ozone (a key component of photochemical smog) is formed by a chemical reaction between NOx and volatile organic compound (VOC) emissions in the presence of sunlight. NOx emission reduction is the key to improve ozone air quality and attain the ozone NAAQS in the Basin. Approximately 85 percent of NOx emissions are from mobile sources in 2018, as shown in Figure 1[1]. Furthermore, NOx emissions, along with VOC emissions, also lead to the secondary formation of PM2.5 in the atmosphere (particulate matter measuring 2.5 micrometer or less in size).

The emission reductions and control measures in the 2022 AQMP rely on commercial adoption of a mix of currently available technologies as well as the expedited development and commercialization of clean fuel mobile and stationary advanced technologies in the Basin to achieve air quality standards. The 2022 AQMP identifies that 83 percent NOx emission reductions from the 2018 level and 67 percent additional reductions in 2037 beyond already adopted regulations and programs are necessary to meet the 2015 8-hour ozone standard by 2037. Figure 2 illustrates the needed NOx reductions in the Basin by source category. The majority of NOx reductions must come from mobile sources, both on-road and off-road categories. Notably, South Coast AQMD is currently one of only two regions in the nation designated as an extreme nonattainment area of the 2015 8-hour ozone NAAQS (the other region is California's San Joaquin Valley).

[1] 2022 South Coast AQMD Air Quality Management Plan, http://www.aqmd.gov/home/air-quality/clean-air-plans/air-quality-mgt-plan

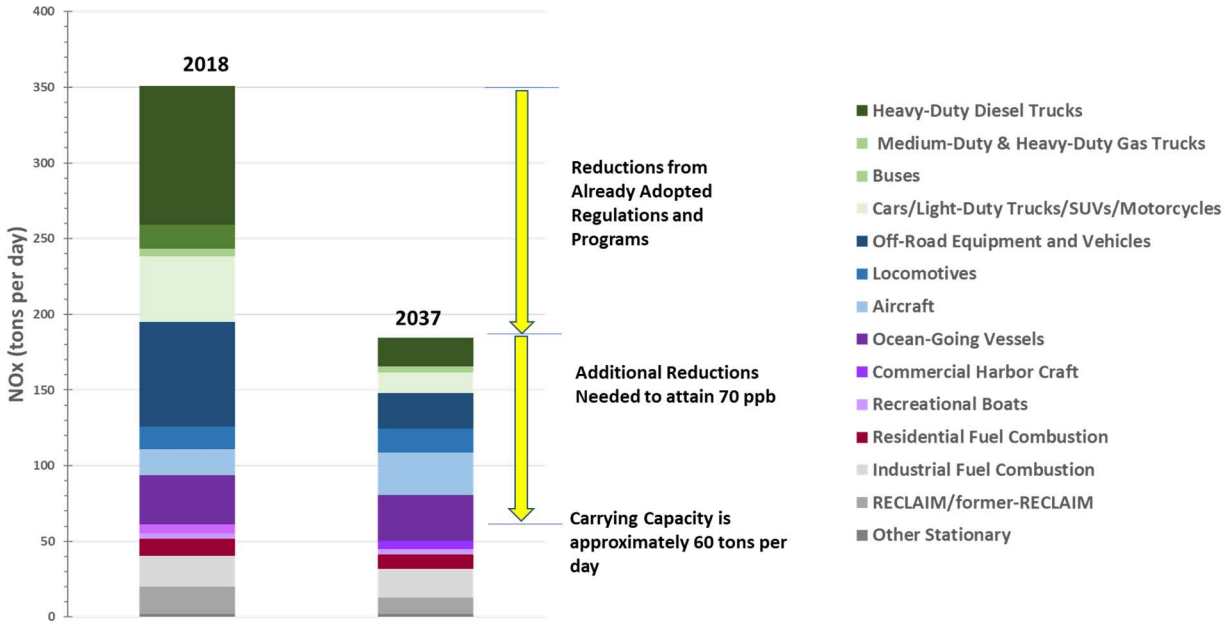


Figure 2: NOx Emissions and Reductions Required to Attain 2015 Ozone Standard in 2037[2]

The 2022 AQMP shows the need for economy-wide transition to zero emission technologies where feasible along with the CARB 2020 Mobile Source Strategy, and low NOx technologies in other applications. To achieve these targets new mobile source technologies are needed to be developed, commercialized, and implemented in a widespread manner.

Clean Fuels Program

The Clean Fuels Program, established in California H&SC 40448.5, is an important mechanism to encourage and accelerate the advancement and commercialization of clean fuels in stationary and mobile source technologies.

Figure 3 provides a conceptual design of the wide scope of the Clean Fuels Program and the relationship with incentive programs. Various stages of technology projects are funded to provide a portfolio of technologies as well as achieve near-term and long-term emission and GHG reductions. The Clean Fuels Program typically funds projects in the Technology Readiness Level (TRL) ranging between 3-8 but does support research projects and early stage of commercial products as needed.

[2] South Coast AQMD 2022 AQMP. Chapter 4, p. 4-2, Figure 4-1. https://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2022-air-quality-management-plan/final-2022-aqmp/07-ch4.pdf?sfvrsn=6

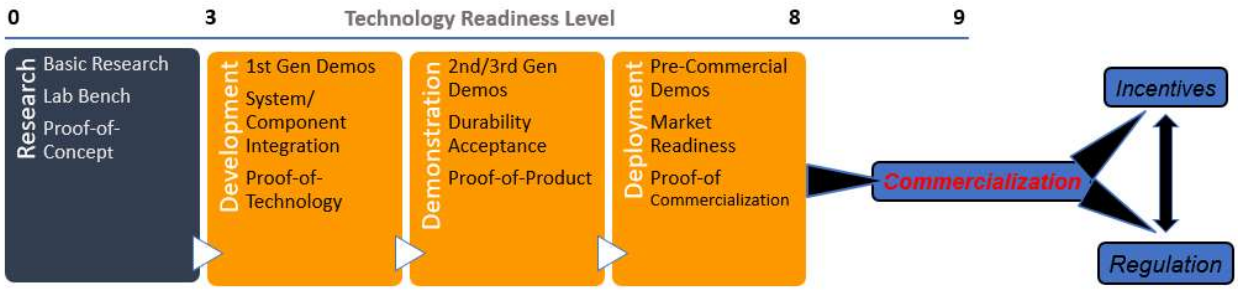


Figure 3: Stages of Clean Fuels Program Funding

Below is a summary of the 2023 Clean Fuels Annual Report and 2024 Plan Update. Every Annual Report and Plan Update is reviewed by two advisory groups–the Clean Fuels Advisory Group, legislatively mandated by SB 98 (chaptered, 1999), and the Technology Advancement Advisory Group, created by the South Coast AQMD Board in 1990. These stakeholder groups review and assess the overall direction of the Program. The two groups meet approximately every six months to provide expert analysis and feedback on potential projects and areas of focus. Key technical experts working in the fields of the Program's core technologies also attend and provide feedback. Preliminary review and comment are also provided by South Coast AQMD's Board and other interested parties and stakeholders. In 2023 the advisory groups met on February 2, 2023 and September 14, 2023.

2023 Annual Report

In CY 2023, the South Coast AQMD Clean Fuels Program executed 19 new contracts and modified three contracts. Also, decreased dollars allocated toward research, development, demonstration and deployment projects as well as technology assessment and transfer of alternative fuel and clean fuel technologies. Table 2 shows major funding partners in CY 2023. Table 4 lists the 22 projects and studies, which are further described in this report. The Clean Fuels Program contributed over $1.4 million in partnership with other governmental organizations, private industry, academia and research institutes, and interested parties, with total project costs of approximately $16.9 million. Additionally, in CY 2023, the Clean Fuels Program continued to leverage outside funding opportunities, securing new awards totaling almost $94 million from federal, state and local funding opportunities. Table 5 provides a comprehensive summary of these federal, state and local revenues awarded to South Coast AQMD during CY 2023. Like the last several years, the significant project scope of a few key contracts executed in 2023 resulted in high leveraging of Clean Fuels dollars. Typical historical leveraging is $4 for every $1 in Clean Fuels funding. In 2023, South Coast AQMD exceeded this upward trend with $13 leveraged for every $1 in Clean Fuels funds. Leveraging dollars and aggressively pursuing federal, state and local funding opportunities is critical, given the magnitude of needed funding identified in the 2022 AQMP to achieve NAAQS.

The projects or studies executed in 2023 included a diverse mix of advanced technologies. The following core areas of technology advancement for 2023 executed contracts (in order of funding percentage) include:

1. Technology Assessment and Transfer/Outreach;
2. Electric and Hybrid Vehicle Technologies and Infrastructure (including battery electric and hybrid electric trucks developed by OEMs and container transport technologies with zero emission operations);
3. Stationary Clean Fuels Technologies (including microgrids and renewables); and
4. Hydrogen and Mobile Fuel Cell Technologies and Infrastructure

Figure 11 on page 27 shows the distribution by percentage of executed agreements in 2023 across these core technologies.

During CY 2023, South Coast AQMD supported a variety of projects and technologies, ranging from near-term to long-term research, development, demonstration and deployment activities. This "technology portfolio" strategy provides South Coast AQMD the ability and flexibility to leverage state and federal funding while also addressing the specific needs of the Basin. Projects included significant battery electric and hybrid electric technologies and infrastructure to develop and demonstrate medium-duty (MD) and HD vehicles in support of transitioning to near-zero and zero emission goods movement; development, demonstration and deployment of large displacement ultra-low NOx engines; and demonstration of hydrogen fuel cell MD and HD vehicles and infrastructure.

In addition to the 22 executed contracts and projects, 16 research, development, demonstration and deployment projects or studies and 17 technology assessment and transfer contracts were completed in 2023, as listed in Table 8 on page 41. Appendix C includes two-page summaries of technical projects completed in 2023. As of January 1, 2024, there were 64 open contracts in the Clean Fuels Program; Appendix B lists these open contracts by core technology.

In accordance with California H&SC Section 40448.5.1(d), this annual report must be submitted to the state legislature by March 31, 2024, after approval by the South Coast AQMD Board.

2024 Plan Update

The Clean Fuels Program is re-evaluated annually to develop the annual Plan Update based on a reassessment of technology progress and direction for the agency. The Program continually seeks to support the development and deployment of cost-effective clean fuel technologies with increased collaboration with OEMs to achieve large scale deployment. The design and implementation of the Clean Fuels Program Plan must balance the needs in the various technology sectors with technology readiness on the path to commercialization, emission and GHG reduction potential and co-funding opportunities. South Coast AQMD is committed to developing, demonstrating and commercializing technologies that reduce criteria pollutants, specifically NOx and toxic air contaminants (TACs). Most of these technologies address the Basin's need for NOx and TAC reductions and garner GHG reductions and petroleum use. Due to these co-benefits, South Coast AQMD has been successful in partnering with the state and public/private partnerships to leverage its Clean Fuels funding.

To identify technology and project opportunities where funding can make a significant difference in deploying cleaner technologies in the Basin, South Coast AQMD engages in outreach and networking efforts. These activities range from close involvement with state and federal collaboratives, partnerships and industrial coalitions, and discussions with OEMS and technology providers on the current state of technologies and development and commercialization challenges. Additionally, unsolicited proposals from OEMs and other clean fuel technology developers are regularly received and reviewed. Potential development, demonstration and certification projects resulting from these outreach and networking efforts are included in the 2024 Clean Fuels Plan Update.

Assembly Bill (AB) 617[3] requires reduced exposure to communities most impacted by air pollution; TAO conducts additional outreach to AB 617 communities regarding available zero and near-zero emission technologies and incentives to accelerate deployment of cleaner technologies. Cleaner technologies such as

[3] https://ww2.arb.ca.gov/capp

zero emission HD trucks are in the Community Emission Reduction Plans (CERPs) for these AB 617 communities, and a zero emission HD truck loaner program is being launched in 2023. This program will allow smaller fleets and independent owner operators to learn about zero emission trucks by trying them out in their business operations. This program is being funded through Community Air Protection Program (CAPP) funds but utilizes zero emission truck technologies developed under the Clean Fuels Program.

Since 2020, CARB has adopted several critical milestone regulations for reducing emissions from on-road HD mobile sources. These regulations include: 1) Advanced Clean Trucks (ACT) regulation which mandates an increasingly higher percentage of zero emission truck sales starting in 2024, 2) Omnibus Low NOx regulation which requires lower exhaust NOx standards on HD engines starting in 2024, 3) HD Vehicle Inspection and Maintenance Program for removing high emitters from legacy trucks, and 4) Advanced Clean Fleets (ACF) regulation which requires fleets to transit to zero-emission trucks starting in 2024. CARB also finalized the 2022 SIP Strategy pending U.S. Environmental Protection Agency (U.S. EPA) approval.

On the federal level, U.S. EPA has adopted a national low NOx truck rule in December 2022. The "Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards," sets more stringent emissions from HD vehicles starting in model year 2027. This regulation is one of three rulemakings planned under the EPA Clean Trucks Plan. Two additional rulemakings include Phase 3 HD GHG standards and light-duty (LD) and MD vehicle muti-pollutant standards for model years 2027 will be finalized by the end of 2023.[4] These EPA regulations have slight differences when compared to CARB counterparts. In August 2023, CARB announced proposed amendments to the Omnibus regulation aligning with the adopted US EPA rule in MY2027 and provisions for allowing the sale of legacy engines starting MY 2024. Both federal and state regulations will together bring much needed mobile source NOx reductions to the Basin.

The South Coast AQMD Warehouse Actions and Investments to Reduce Emissions (WAIRE) program established as a part of Warehouse Indirect Source Rule (ISR) adoption reduces NOx and diesel particulate matter (DPM) emissions from mobile sources that are attracted to the Warehouses. The San Pedro Bay Ports implemented the Clean Truck Fund (CTF) to generate funds for achieving the goal of zero emission drayage trucks by 2035. Despite all these major efforts, per the 2022 AQMP, additional NOx emission reductions in the Basin are needed to meet ozone attainment target deadlines.

The Plan Update includes projects to develop, demonstrate and commercialize a variety of technologies, from near-term to long-term commercialization, that are intended to provide significant emission reductions over the next five to ten years. Areas of focus include:

- developing and demonstrating technologies to reduce emissions from goods movement and port-related activities, including zero emission drayage trucks, equipment and infrastructure;
- understanding particulate emissions from tire and brake wear;
- demonstrating ultra-low NOx, gaseous and liquid alternative/renewable fueled, large displacement/high efficiency engines and HD zero emission technologies;
- mitigating criteria pollutant emissions from the production of renewable fuels, such as renewable natural gas, diesel, hydrogen, and electricity as well as other renewable, low/zero carbon fuels and waste streams;

[4] Final Rule and Related Materials for Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards | US EPA

- producing transportation fuels and energy from renewable and waste stream sources;
- developing and demonstrating electric-drive (fuel cell, battery, plug-in hybrid and non-plug-in hybrid) technologies across LD, MD and HD platforms;
- establishing large-scale hydrogen fueling and electric vehicle (EV) charging infrastructure to support MD and HD zero emission vehicles;
- ultra-fast, higher power charging (1 megawatt (MW)) for HD battery electric vehicles;
- developing and demonstrating high flow fueling protocols and standards to address hydrogen refueling station network health and reliability and expand HD hydrogen refueling stations;
- developing and demonstrating portable hydrogen refueling equipment to address the short-term need for hydrogen refueling and advance these technologies;
- developing and demonstrating green hydrogen production pathways and hydrogen ecosystem to reduce the cost of hydrogen and improve state-wide hydrogen station reliability and availability;
- developing and demonstrating low and zero emission alternative charging solution (ACS) technologies to support delay in deploying permanent EV charging infrastructure or to provide temporary and/or backup power generation; and
- developing and demonstrating zero emission microgrids that utilize battery energy storage systems and onsite clean power generation to support transportation electrification demands associated with goods movement and freight handling activities.

Table 9 (page 63) lists potential projects across ten core technologies by funding priority:

- Zero Emission Infrastructure (especially large-scale fueling and production facilities and private and public stations as well as ACS that support MD and HD vehicles);
- Hydrogen / Mobile Fuel Cell Technologies;
- Electric / Hybrid Technologies (battery electric and hybrid electric trucks and container transport technologies with zero emission operations);
- Stationary Clean Fuel Technologies (microgrids and stationary clean fuel technology projects, but not in combination with EV and Hydrogen infrastructure);
- Fuel and Emission Studies;
- Renewable Fuel Infrastructure;
- Health Impact Studies within disadvantaged communities;
- Technology Assessment and Transfer/Outreach;
- Engine Systems / Technologies (alternative and renewable fuels for truck and rail applications); and
- Emission Control Technologies.

These potential projects for 2024 total $33 million of Clean Fuels funding, with the anticipation of total project costs of $556.8 million, leveraging almost $17 for every $1 of Clean Fuel funds spent. Some proposed projects may also be funded by other funding sources, such as state and federal grants for clean fuel technologies, incentive programs such as AB 617 CAPP funding, Volkswagen Mitigation, and Carl Moyer, and other mitigation funds.

CLEAN FUELS PROGRAM

Background and Overview

Program Background

The South Coast Air Basin (Basin), which comprises all of Orange County and the urban portions of Los Angeles, San Bernardino and Riverside counties, has the worst air quality in the nation due to a combination of factors, including high vehicle population, high vehicle miles traveled within the region, and geographic and atmospheric conditions favorable for photochemical oxidant (smog) formation. This region, which encompasses the Basin as well as small portions of the Mojave Desert and Salton Sea Air Basins, is home to almost 18 million residents (nearly half the population of California). Due to this confluence of factors, which present unique challenges, the state legislature enabled South Coast AQMD to implement the Clean Fuels Program to accelerate the implementation and commercialization of clean fuels and advanced mobile source technologies.

In 1988, Senate Bill (SB) 2297 (Rosenthal) was signed into law (Chapter 1546). It initially established a "five-year program to increase the use of clean fuels," but subsequent legislation extended and eventually removed the sunset clause for the Program. That legislation also reaffirmed existence of the Technology Advancement Office (TAO) to administer the Clean Fuels Program. The Clean Fuels Program is an integral part of South Coast AQMD's effort to achieve the significant nitrogen oxides (NOx) reductions called for in the 2022 AQMP.

California Health and Safety Code (H&SC) section 40448.5(e) calls for the Clean Fuels Program to consider, among other factors, current and projected economic costs and availability of fuels, cost-effectiveness of emission reductions associated with clean fuels compared with other pollution control alternatives, use of new pollution control technologies in conjunction with traditional fuels as an alternative means of reducing emissions, potential effects on public health, ambient air quality, visibility within the region, and other factors determined to be relevant by South Coast AQMD. The Legislature recognized the need for flexibility, allowing focus on a broad range of technology areas, including cleaner fuels, vehicles and infrastructure, which helps South Coast AQMD continue to make progress toward achieving its clean air goals.

In 1999, further state legislation was passed which amended the Clean Fuels Program. Specifically, as stated in the H&SC section 40448.5.1(d), South Coast AQMD must submit an annual report to the Legislature, on or before March 31, that includes:

1. Description of the core technologies that South Coast AQMD considers critical to ensure attainment and maintenance of ambient air quality standards and a description of the efforts made to overcome barriers to commercialization of those technologies;
2. Analysis of the impact of South Coast AQMD's Clean Fuels Program on the private sector and on research, development and commercialization efforts by major automotive and energy firms, as determined by South Coast AQMD;
3. Description of projects funded by South Coast AQMD, including a list of recipients, subcontractors, co-funding sources, matching state or federal funds and expected and actual results of each project advancing and implementing clean fuels technology and improving public health;

4. Title and purpose of all projects undertaken pursuant to the Clean Fuels Program, names of the contractors and subcontractors involved in each project and amount of money expended for each project;
5. Summary of progress made toward the goals of the Clean Fuels Program; and
6. Funding priorities identified for the next year and relevant audit information for previous, current and future years covered by the Clean Fuels Program.

Furthermore, H&SC section 40448.5.1(a)(2) requires South Coast AQMD to find that the proposed program and projects funded as part of the Clean Fuels Program will not duplicate any other past or present program or project funded by the state board and other government and utility entities. This finding does not prohibit funding for programs or projects jointly funded with another public or private agency where there is no duplication. Concurrent with adoption and approval of the annual report and plan update every year, the Board will consider the efforts TAO has undertaken in the prior year to ensure no such duplication has occurred then make a finding through a Resolution attesting such.

The following section describes the various panels of external experts that help review the Clean Fuels Program every year.

Program Review

In 1990, South Coast AQMD initiated an annual review of its technology advancement program by an external panel of experts. That external review process has evolved, in response to South Coast AQMD policies and legislative mandates, into two external advisory groups. The Technology Advancement Advisory Group (one of six standing Advisory Groups that make up the South Coast AQMD Advisory Council) is made up of stakeholders representing industry, academia, regulatory agencies, scientific community and environmental non-governmental organizations (NGOs). The Technology Advancement Advisory Group serves to:

- Coordinate the Clean Fuels program with related local, state and national activities;
- Review and assess the overall direction of the program; and
- Identify new project areas and cost-sharing opportunities.

In 1999, the second advisory group was formed as required by SB 98 (Alarcon). Under H&SC Section 40448.5.1(c), this advisory group must comprise 13 members with expertise in clean fuels technology and policy or public health and appointed from the scientific, academic, entrepreneurial, environmental and public health communities. This legislation further specified conflict-of-interest guidelines prohibiting members from advocating expenditures towards projects in which they have professional or economic interests. The objectives of the SB 98 Clean Fuels Advisory Group are to make recommendations regarding projects, plans and reports, prior to submittal of the required annual report to the South Coast AQMD Governing Board. In 1999, after formation of the SB 98 Clean Fuels Advisory Group, South Coast AQMD revisited the charter and membership of the Technology Advancement Advisory Group to ensure their functions would complement each other.

On an as-needed basis, changes to the composition of the Clean Fuels Advisory Group are reviewed by the South Coast AQMD Board while changes to the Technology Advancement Advisory Group are reviewed by the South Coast AQMD Board's Technology Committee.

The charter for the Technology Advancement Advisory Group calls for approximately 12 technical experts representing industry, academia, state agencies, scientific community and environmental interests.

Traditionally, there has been exactly 12 members on this advisory group, but in CY 2019 staff recommended to the Board's Technology Committee that it add representatives from the Ports of Long Beach and Los Angeles, as both entities are integral players and stakeholders in demonstrating near-zero and zero emission technologies in and around the Ports and surrounding disadvantaged communities. With the addition of the Port representatives, there are currently 13 members on the Technology Advancement Advisory Group.

Current membership changes to both advisory groups are considered by the South Coast AQMD Board and its Technology Committee, respectively, as part of consideration of each year's Annual Report and Plan Update. Members of the SB 98 Clean Fuels Advisory Group and Technology Advancement Advisory Group are listed in Appendix A, with proposed changes, duly noted, subject to either South Coast AQMD Board approval or the Board's Technology Committee, per the advisory group's charters.

The review process of the Clean Fuels Program now includes, at minimum: 1) two full-day retreats of both Advisory Groups, typically in the summer and winter; 2) review by other technical experts; 3) occasional technology forums or roundtables bringing together interested parties to discuss specific technology areas; 4) review by the Technology Committee of the South Coast AQMD Board; 5) public hearing of the Annual Report and Plan Update before the full South Coast AQMD Board, along with adoption of the Resolution finding that the proposed program and projects funded as part of the Clean Fuels Program will not duplicate any other past or present program or project funded by the state board and other government and utility entities, as required by the H&SC; and 6) annual submittal of the Clean Fuels Program Annual Report and Plan Update to the Legislature by March 31.

The Need for Advanced Technologies & Cleaner Fuels

Achieving federal and state clean air standards in the Basin will require emission reductions from both mobile and stationary sources beyond those expected using current technologies.

Ground level ozone (a key component of smog) is created by a chemical reaction between NOx and volatile organic compound (VOC) emissions in sunlight. This is noteworthy because the primary driver for ozone formation in the Basin is NOx emissions, and mobile sources contribute approximately 85 percent of the NOx emissions in this region, as shown in Figure 4. Furthermore, NOx emissions, along with VOC emissions, also lead to the formation of PM2.5 [particulate matter measuring 2.5 microns or less in size, expressed as micrograms per cubic meter (µg/m3)], including secondary organic aerosols.

To fulfill near- and long-term emission reduction targets, the 2022 AQMP currently relies on a mix of currently available technology as well as accelerated development and demonstration of advanced technologies that are not yet commercialized. Significant reductions are anticipated from implementation of advanced control technologies for on-road and off-road mobile sources. Air quality standards for ozone (70 ppb, 8-hour average) and fine particulate matter, promulgated by U.S. Environmental Protection Agency (U.S. EPA), are projected to require additional long-term control measures for NOx and VOC.

The need for advanced mobile source technologies and clean fuels is best illustrated by Figure 4 which identifies NOx emissions by source category in 2018 and 2037. NOx reductions identified in the 2022 AQMP will require the Clean Fuels Program to accelerate advancement of clean transportation technologies used as control strategies in the AQMP. Given this contribution, significant emission reductions from these sources are needed. 2022 AQMP mobile source strategies call for deploying cleaner technologies (both zero and near-zero emission) into fleets, requiring cleaner and renewable fuels, and ensuring continued clean performance in use. Federal actions are also required to address sources that are subject to federal regulations and beyond the regulatory authority of South Coast AQMD and California Air Resources Board

(CARB).

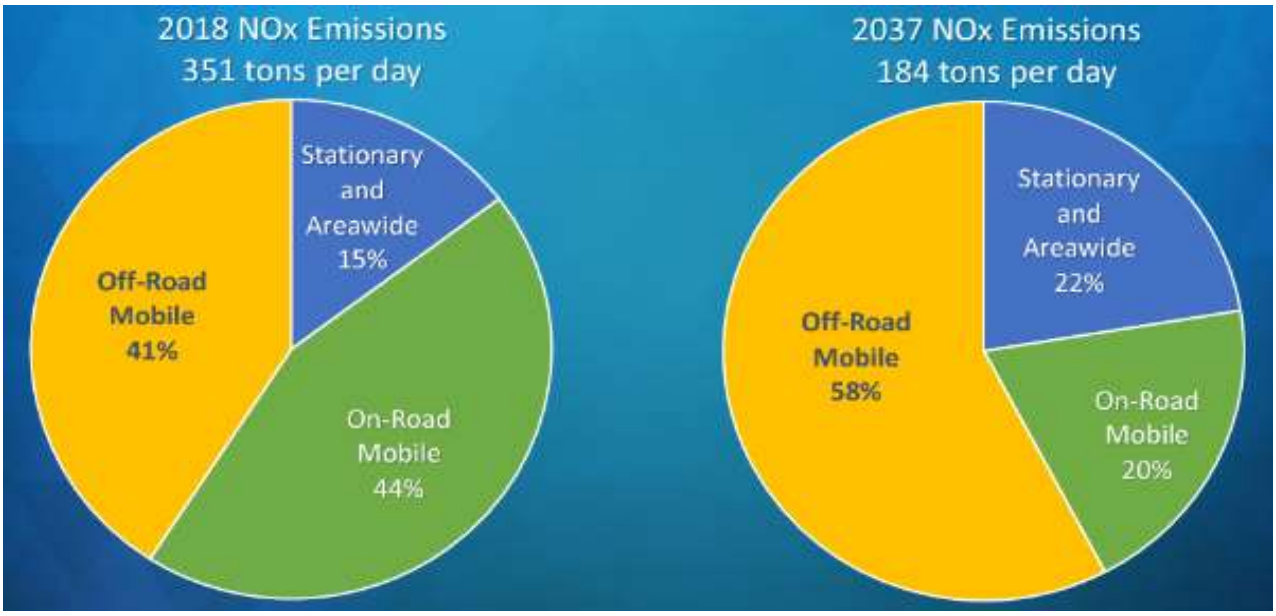


Figure 4: NOx Contribution Source Category in 2018 and 2037

Health studies also indicate a greater need to reduce NOx emissions and TAC emissions. The South Coast AQMD Multiple Air Toxics Exposure Study (MATES) V study (2021), and the prior four MATES studies, assessed air toxic levels, updated risk characterization, and determined gradients from selected sources. MATES VI is currently underway and will expand on the prior MATES studies.

In summary, advanced, energy efficient and renewable technologies are needed for attainment, but also to protect the health of residents, reduce long-term dependence on petroleum-based fuels, and support a more sustainable energy future. Conventional strategies and traditional supply and consumption need to be retooled to achieve national ambient air quality standards (NAAQS). To meet this need for advanced, clean technologies, the South Coast AQMD Board continues to aggressively carry out the Clean Fuels Program and promote alternative fuels through its TAO.

As technologies move towards commercialization, such as battery electric and fuel cell trucks, the Clean Fuels Program partners with large OEMs, such as Daimler Trucks North America, LLC (DTNA), Volvo and Kenworth, to deploy these vehicles at scale. These OEM partnerships allow the Program to leverage the research, product creation and financial resources that are needed to move advanced technologies from the laboratories to the field and into customers' hands. OEMs have the resources and abilities to design, engineer, test, manufacture, market, distribute and service quality products under brand names that are trusted. This is the type of scale needed to achieve emission reductions to meet NAAQS.

As advanced technologies and cleaner fuels are commercial-ready, there needs to be a concerted effort to get them into the marketplace and on the roads. South Coast AQMD's Carl Moyer Program, which was launched in 1988, along with recent Volkswagen Mitigation Trust and Community Air Protection Program (CAPP), help achieve these results. These programs provide incentives to push market penetration of the technologies developed and demonstrated by the Clean Fuels Program. The synergy between the Clean Fuels program and incentive programs enable South Coast AQMD to play a leadership role in both technology development and commercialization efforts targeting reduction of criteria pollutants. Funding for both research, development, demonstration and deployment (RD[3)] projects as well as incentives remains

critical given the magnitude of additional funding identified in the 2022 AQMP to achieve NAAQS.

Emission Reductions Resulting from Clean Fuels Program

The Clean Fuels Program has encouraged projects that increase the utilization of clean-burning fuels over the 35-year lifetime of the program. Many of the technologies that were supported during the early years of the program, are now seeing commercial deployments, e.g. fuel cell buses, while others saw great success only to be eventually phased out, e.g., methanol buses and vehicles. Of all the technologies that the Clean Fuels Program have supported, there are two recent technologies that have been commercialized and are providing emissions benefits through incentives programs, ultra-low NOx (near-zero emission or NZE) NG engines and zero emission trucks (ZETs).

The Clean Fuels Program has been supporting the development of low and near-zero emission HD NG engines since the early 2000's. In 2003, South Coast AQMD conducted a joint project with California Energy Commission (CEC), U.S. Department of Energy (DOE) and National Renewable Energy Laboratory (NREL) to advance development of HD NG engines to meet the upcoming 2010, 0.2 grams per brake horsepower hour (g/bhp-hr) NOx standard. The result was the Cummins-Westport, Inc (CWI) 8.9-liter engine that certified to 0.2 g NOx/bhp-hr, three years before the mandated 2010 national standard. In 2013, recognizing the need for accelerated NOx reductions in the HD sector, South Coast AQMD, CEC, and Southern California Gas Company (SoCalGas) issued a joint solicitation to develop and demonstrate an NZE engine for commercial use. CWI developed and commercialized the first 0.02 g/bhp-hr NOx 8.9-liter NG engine (L9N). Additional projects with CEC, SoCalGas and Clean Energy produced the CWI 11.9-liter NZE engine (ISX12N) certified in 2018 for port fleet operations, also first of its kind, including a 20-truck demonstration project at the San Pedro Bay Ports. These engines are now commercially available and offered by all major truck OEMs.

The Clean Fuels Program has also supported the development of ZETs including battery electric trucks (BETs) and fuel cell electric trucks (FCETs). DOE funded the Zero Emission Cargo Transport 1 (ZECT 1) project developed and demonstrated Class 8 BETs. The ZECT 1 project gave birth to many other BET and hybrid truck projects, including subsequent projects such as the CARB Greenhouse Gas Reduction Fund (GGRF) Zero Emission Drayage Truck (ZEDT) project, which demonstrated 44 battery electric and CNG and diesel hybrid electric drayage trucks at multiple California Ports. The ZEDT project included 25 BYD 8TT BETs, 12 Peterbilt/Meritor/ TransPower 579 BETs, two Kenworth CNG hybrid electric trucks based on their T680 daycab, three Volvo diesel plug-in hybrid electric trucks, and two Volvo VNR Electric BETs. More recently, the Clean Fuels Program co-funded large Daimler and Volvo BET projects. For the Daimler Innovation Fleet project, Daimler deployed 14 Class 8 eCascadia and six Class 6 eM2 trucks and installed seven DC fast charging stations at fleet locations in 2019. Volvo deployed 30 Class 8 BETs and installed Level 2, AC, 50 and 150 kW DC fast chargers, and solar/storage as part of their CARB GGRF Low Impact Green Heavy Transport Solutions (LIGHTS) in 2022. Daimler deployed two Class 6 and six Class 8 BETs for its Customer Experience project which will be completed in 2023. Daimler will be deploying 15 Class 6 and 20 Class 8 BETs and chargers for commercial fleet distribution/delivery operations for its Zero Emission Electric Delivery Trucks project which will be completed in 2024. In 2021, South Coast AQMD was awarded CARB and CEC funding for the Joint Electric Truck Scaling Initiative (JETSI) Pilot project to deploy 100 BETs and 350 kW DC fast chargers for two fleets, NFI Interactive Logistics, LLC (NFI) and Schneider National Inc (Schneider). The Volvo VNR Electric truck and DTNA eCascadia will be deployed in 2023 and are commercially available. Examples of BETs that South Coast AQMD has developed and demonstrated with co-funding from various partners are shown in Figure 5.

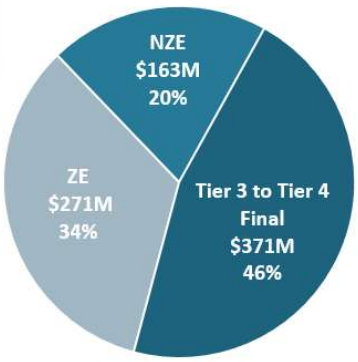
Figure 5: Developed and Demonstrated Clean Fuel Technology Trucks

To quantify some of the emissions benefit from NZE and ZE truck deployments, Table 1 summarizes the potential emissions reductions as result of the technologies directly supported by the Clean Fuels Program. South Coast AQMD staff compiled incentive program data between 2018 and 2023 from our Technology Incentives Group to calculate the NOx emissions reductions associated with deployment projects of NZE and ZE heavy-duty vehicles (HDVs) in the Basin. Note the programs below required scrappage, that meant each vehicle deployed eliminated an older diesel truck, and the emission reductions are based on the program guidelines established by CARB.

Table 1: Emissions Benefits from Incentive Programs (2018-2023)

Technology Type	Award Amount	NOx Reductions (tons)	PM Reductions (tons)
Zero Emission	$271M	137.5	1.9
Near-Zero Emission	$163M	773.1	13.7
Tier 3 to Tier 4 Final	$371M	2,421.2	71.2
Total	$804M	3,332.7	86.8

Includes funded projects from Carl Moyer, Proposition 1B, VW Mitigation Trust, and Lower Emission School Bus programs



Although the emission reductions may seem modest, these technologies represent almost 4% of the total

emission reductions for on-road HD diesel trucks in 2023[5], and the numbers will only continue to grow, thanks in part to the support by the Clean Fuels Program.

Program Funding

The Clean Fuels Program is established under H&SC Sections 40448.5 and 40512 and Vehicle Code Section 9250.11. This legislation establishes mechanisms to collect revenues from mobile and stationary sources to support the program objectives and identifies the constraints on the use of funds. In 2008, these funding mechanisms were reauthorized under SB 1646 (Padilla), which removed the funding sunset of January 1, 2010, and established the five percent administrative cap instead of the previous cap of two-and-half percent.

Specifically, the Clean Fuels Program is funded through a $1 fee on motor vehicles registered in the South Coast AQMD. Revenues collected from these motor vehicles must be used to support mobile source projects. Stationary source projects are funded by an emission fee surcharge on stationary sources emitting more than 250 tons of pollutants per year within South Coast AQMD. This revenue is typically about $13.5 million and $350,000, respectively, every year. For CY 2023, the funds available through each of these mechanisms were as follows:

- Mobile sources (DMV revenues) $13,689,363
- Stationary sources (emission fee surcharge) $249,879

The Clean Fuels Program also receives grants and cost-sharing revenue contracts from various agencies, on a project-specific basis, that supplement the South Coast AQMD program. Historically, such cooperative project funding revenues have been received from CARB, CEC, U.S. EPA (including but not limited to their Diesel Emissions Reduction Act or DERA, Clean Air Technology Initiative or CATI, and Airshed programs), DOE and U.S. Department of Transportation (DOT). These supplemental revenues depend in large part on the originating agency, its budgetary and planning cycle and the specific project or intended use of the revenues.

Table 5 on page 29 lists the federal, state and other revenue totaling almost $94 million awarded to South Coast AQMD in 2023 for projects that are part of the overall Clean Fuels Program's RD^3 efforts, even if for financial tracking purposes revenue is recognized into another special revenue fund other than the Clean Fuels Fund (Fund 31).

The final and perhaps most significant funding source can best be described as an indirect source, i.e., funding not directly received by South Coast AQMD. This indirect source is the cost-sharing provided by private industry and other public and private organizations. The public-private partnerships with private industry, technology developers, academic institutions, research institutions and government agencies are a key strategy of the Clean Fuels Program. Historically, the TAO has been successful in leveraging its available public funds with $4 of outside funding for each $1 of South Coast AQMD funding. Since 1988, the Clean Fuels Program has leveraged nearly $267.9 million into over $1.7 billion in projects. For 2023, the Clean Fuels Program leveraged $1 of Clean Fuels Funds to $13 of outside funding. This leverage was the result of three key significant project awards for a hydrogen fuel cell mobile power generation system, the deployment of fuel cell transit buses and the deployment of zero emission mobile clinics in 2023. Through these public-private partnerships, South Coast AQMD shared the investment risk of developing new technologies along with the benefits of expedited development and commercial availability, increased

[5] 1.69 tpd reductions vs. 44.5 tpd in on-road heavy-duty diesel inventory in 2023.

end-user acceptance, reduced emissions from demonstration projects and ultimately increased use of clean technologies in the Basin. While South Coast AQMD aggressively seeks to leverage funds, it continues to act in a leadership role in technology development and commercialization efforts, along with its partners, to accelerate the reduction of criteria pollutants. Leveraging dollars and aggressively applying for additional funds whenever funding opportunities arise is more important than ever given, as previously noted, the magnitude of additional funding identified in the 2022 AQMP to achieve NAAQS. The Clean Fuels Program has also avoided duplicative efforts by coordinating and jointly funding projects with major funding agencies and organizations. The major funding partners for 2023 are listed in Table 2 on page 20.

2023 Overview

This report summarizes the progress of the Clean Fuels Program for CY 2023. The Clean Fuels Program cost-shares projects to develop and demonstrate zero, near-zero and low emissions clean fuels and advanced technologies to advance technology and promote commercialization and deployment of promising or proven technologies not only for the Basin but Southern California and the nation as well. These projects are conducted through public-private partnerships with industry, technology developers, academic and research institutes and local, state and federal agencies.

This report also highlights achievements and summarizes project costs of the Clean Fuels Program in CY 2023. During the period between January 1 and December 31, 2023, South Coast AQMD executed 19 new contracts/agreements, projects or studies and modified 3 continuing projects adding dollars during CY 2023 that support clean fuels and advanced zero, near-zero and low emission technologies (see Table 4). The Clean Fuels Program contribution for these projects was over $1.4 million as cost-share for contracts executed in this reporting period. Total project costs are over $16.9 million.

The projects executed in 2023 address a wide range of issues with a diverse technology mix including near-term emissions reductions and long-term planning efforts. The report not only provides information on outside funding received into the Clean Fuels Fund as cost-share for contracts executed in this period, but also funds awarded to South Coast AQMD for projects that fall within the scope of the Clean Fuels Program's RD^3 efforts but may have been recognized (received) into another special revenue fund for financial tracking purposes (nearly $94 million in 2023, see Table 5). In 2023, the South Coast AQMD was awarded the following from US EPA: $10 million for demonstration of a plug-in hybrid tugboat; over $6.1 million for demonstration of fuel cell trucks and battery electric asphalt compactors; and $500,000 for development of a zero-emission electric power take-off system work truck. Other RD^3 awards in 2023 include $500,000 from DOE for demonstration of a fuel cell locomotive, $600,000 from San Pedro Bay Ports for an ocean going vessel (OGV) retrofit project, and over $76.2 million from California State Transportation Agency (CalSTA) for deployment of HD truck charging and fueling infrastructure. More details on this financial summary are in this report. South Coast AQMD will continue to pursue federal, state and private funding opportunities in 2024 to amplify leverage, while acknowledging that support of a promising technology is not contingent on outside cost-sharing and affirming that South Coast AQMD will remain committed to playing a leadership role in developing advanced technologies that lower criteria pollutants.

Core Technologies

Given the diversity of sources that contribute to the air quality problems in the Basin, there is no single technology or "Silver Bullet" that can solve all the problems. A number of technologies are required, and these technologies represent a wide range of applications, with full emissions benefit "payoffs," i.e., full commercialization and mass deployment occurring at different times. The broad technology areas of focus

– the "Core Technologies" – for the Clean Fuels Program are as follows:

- Hydrogen / Mobile Fuel Cell Technologies and Infrastructure;
- Engine Systems / Technologies (including alternative and renewable fuels for truck and rail applications);
- Electric / Hybrid Vehicle Technologies and Related Infrastructure (including battery electric and hybrid electric trucks and container transport technologies with zero emission operations);
- Fueling Infrastructure and Deployment (NG and renewable fuels);
- Stationary Clean Fuels Technologies (including microgrids and renewables);
- Fuel and Emissions Studies;
- Emissions Control Technologies;
- Health Impacts Studies; and
- Technology Assessment and Transfer / Outreach.

At its January 2023 retreat, the Technology Advancement and SB-98 Clean Fuels Advisory Groups asked staff to take another look at these core technologies to determine if they still fit within the strategy of the Clean Fuels Program. That effort will be undertaken in 2024.

South Coast AQMD continually seeks to support the deployment of lower-emitting technologies. The Clean Fuels Program is shaped by two basic factors:

1. Zero, near-zero and low emission technologies needed to achieve clean air standards in the Basin; and
2. Available funding to support technology development within the constraints imposed by that funding.

South Coast AQMD strives to maintain a flexible program to address dynamically evolving technologies and the latest progress in the state of the technology while balancing the needs in the various technology sectors with technology readiness, emissions reduction potential and co-funding opportunities. Although the Clean Fuels Program is significant, national and international activities affect the direction of technology trends. As a result, the Clean Fuels Program must be flexible to leverage and accommodate these changes in state, national and international priorities. Nonetheless, while state and federal governments have continued to turn a great deal of their attention to climate change, South Coast AQMD has remained committed to developing, demonstrating and commercializing zero and near-zero emission technologies. Fortunately, many, if not the majority, of technology sectors that address our need for NOx reductions also garner GHG reductions. Due to these "co-benefits," South Coast AQMD has been successful in partnering with state and federal government. Even with leveraged funds, the challenge for South Coast AQMD remains the need to identify project or technology opportunities in which its available funding can make a difference in achieving progressively cleaner air in the Basin.

To achieve this, South Coast AQMD employs various outreach and networking activities as well as evaluates new ways to expand these activities. These activities range from close involvement with state and federal collaboratives, partnerships and industrial coalitions, to the issuance of PONs to solicit project ideas and concepts as well as the issuance of RFIs to determine the state of various technologies and the development and commercialization challenges faced by those technologies. Additionally, in the absence of PONs, unsolicited proposals from OEMs and other clean fuel technology developers are accepted and reviewed.

Historically, mobile source projects have targeted low-emission developments in automobiles, transit buses, MD and HD trucks and non-road applications. These vehicle-related efforts have focused on advancements

in engine design, electric powertrains and energy storage/conversion devices (e.g., fuel cells and batteries); and implementation of clean fuels (e.g., NG, propane and hydrogen) including infrastructure development. Stationary source projects have included a wide array of advanced low NOx technologies and clean energy alternatives such as fuel cells, solar power and other renewable and waste energy systems. The focus in recent years has been on zero and near-zero emission technologies with increased attention to HD and MD trucks to reduce emissions from mobile sources, which contribute to more than 80 percent of the current NOx emissions in this region. However, while mobile sources include both on- and off-road vehicles as well as aircraft and ships, only the federal government has the authority to regulate emissions from aircraft and ships. South Coast AQMD is exploring opportunities to expand its authority in ways that would allow the agency to do more to foster technology development for ship and train activities as well as locomotives related to goods movement. In the absence of regulatory authority, South Coast AQMD is expanding its portfolio of RD^3 projects to include marine and ocean-going vessels. Utilizing mitigation funds, funding from San Pedro Bay Ports and industry partners, RD^3 projects to demonstrate emissions reduction technology in the marine sector where NOx emissions are increasing are being pursued.

The 2022 AQMP included five facility-based mobile source measures, also known as indirect source measures. Staff has been developing both voluntary and regulatory measures in a process that has included extensive public input. Indirect source measures are distinct from traditional air pollution control regulations in that they focus on reducing emissions from the vehicles associated with a facility rather than emissions from a facility itself.

For example, newly established indirect source measures for warehouses focuses on reducing emissions from trucks servicing the warehouse. Measures for Ports will concentrate on emissions from ships, trucks, locomotives and cargo handling equipment at the Ports. Measures covering new development and redevelopment projects could aim to reduce emissions from construction equipment, particularly HD diesel earth-moving vehicles.

Specific projects are selected for co-funding from competitive solicitations, cooperative agency agreements and unsolicited proposals. Criteria considered in project selection include emissions reduction potential, technological innovation, potential to reduce costs and improve cost effectiveness, contractor experience and capabilities, overall environmental impacts or benefits, commercialization and business development potential, cost-sharing and cost-sharing partners, and consistency with program goals and funding constraints. The core technologies for South Coast AQMD programs that meet both the funding constraints and 2022 AQMP needs for achieving clean air are briefly described below.

Hydrogen / Mobile Fuel Cell Technologies and Infrastructure

Toyota and Hyundai commercialized LD fuel cell vehicles in 2015 and Honda started delivering their Fuel Cell Clarity in 2016. OEMs continue development efforts and collaborate to broaden application of fuel cells to increase manufacturing scale and reduce cost to commercialize fuel cell vehicles. However, although progress is being made, the greatest challenge for the viability of fuel cell vehicles remains the installation and operation of hydrogen fueling stations. AB 8 requires CEC to allocate $20 million annually from the Alternative and Renewable Fuel and Vehicle Technology Program until there are at least 100 publicly accessible hydrogen stations in operation in California. Of the 107 stations funded by CEC and CARB by the end of 2022, partially funded by South Coast AQMD for those in our region, there is one legacy and 54 retail operational in California. CEC and CARB staff expect that California will exceed the 100-station goal in AB 8 in 2023, with more than 179 stations by 2027. AB 8 also requires CARB to annually assess current and future fuel cell vehicles (FCVs) and hydrogen stations in the marketplace. *The Joint Agency Staff Report on Assembly Bill 8: 2021 Annual Assessment of Time and Cost Needed to Attain*

100 Hydrogen Refueling Stations in California[6] released in December 2021 covering 2021 findings states that there were 9,647 fuel cell vehicles registered in California by October 2021. CARB's 2022 Annual Evaluation projects 37,500 fuel cell electric vehicles (FCEVs) in California by 2025 and 65,600 by the end of 2028, after accounting for estimated vehicle retirements. Additionally, the California Fuel Cell Partnership's (CaFCP) *The California Fuel Cell Revolution, A Vision For Advancing Economic, Social, and Environmental Priorities* (Vision 2030) includes the need for up to 1,000 refueling stations statewide as well as the need for 200 HD stations to support 70,000 fuel cell trucks by 2035.

Clearly, South Coast AQMD must continue to support infrastructure required to refuel retail fuel cell vehicles and the nexus to MD and HD trucks including reducing the cost to deploy HD hydrogen infrastructure. To that end, South Coast AQMD co-funded a liquid hydrogen station capable of fueling up to 50 fuel cell transit buses and 10 fuel cell transit buses at OCTA. South Coast AQMD Clean Fuels funding of $1,000,000 is committed towards the CARB Zero and Near Zero-Emission Freight Facilities (ZANZEFF) Shore to Store project to deploy 10 HD FCETs and install three HD hydrogen stations in Wilmington and Ontario; this contract is also supported by the $1,200,000 Clean Fuels funding committed to the CEC co-funded HD Shell station on Port of Long Beach (POLB) property leased to Toyota. South Coast AQMD is also actively engaged in finding alternatives to reduce the cost of hydrogen (e.g., large-scale hydrogen refueling stations or production facilities) and potential longer-term fuel cell power plant technology. South Coast AQMD is also administering the DOE-funded ZECT project (ZECT 2), to develop and deploy six HD drayage FCETs. Two FCETs are manufactured by Transportation Power Inc. (TransPower), two FCET by US Hybrid, one FCET by Kenworth, and one FCET by Hydrogenics (a Cummins Inc. company). Six of the seven vehicle designs, and integration, are completed, and four of the FCETs are in demonstration. The battery and fuel cell dominant FCETs have a range of 150-200 miles.

South Coast AQMD also cofounded research studies on hydrogen systems and HD hydrogen fueling infrastructure, and high-flow bus fueling protocols that are led by UC Davis, DOE, and NREL.

Engine Systems / Technologies

MD and HD on-road vehicles contributed approximately 23 percent of the Basin's 2018 NOx emissions inventory based on 2022 AQMP data. More importantly, on-road HD diesel trucks account for 33 percent of the on-road mobile source PM2.5, a known TAC. Furthermore, according to CARB, trucks and buses are responsible for 37 percent of California's GHGs and criteria emissions. While MATES IV found a dramatic decrease in ambient levels of diesel PM and other air toxics, diesel PM is still the major driver of air toxics health risks. Clearly, significant emission reductions will be required from mobile sources, especially from the HD sector, to attain the NAAQS. Even with the announced rollout of ZETs in 2021 by Volvo and Daimler, it is anticipated that it would take ten years for a large enough deployment of those trucks to have an impact on air quality.

The use of alternative fuels in HD vehicles can provide significant reductions in NOx and particulate emissions. The current NOx emissions standard for HD engines is 0.2 g/bhp- hr. South Coast AQMD, along with various local, state and federal agencies, continues to support the development and demonstration of alternative-fueled low emission HD engine technologies, using NG, renewable natural gas or hydrogen, renewable diesel and potentially other renewable or waste stream fuels, for applications in HD trucks, transit and school buses, rail operations, and refuse collection and delivery vehicles to meet future federal emission standards. South Coast AQMD is supporting three contracts to convert the model year 2021 new Ford MD gasoline engine to near-zero NOx level by using NG and propane.

[6] https://www.energy.ca.gov/publications/2021/joint-agency-staff-report-assembly-bill-8-2021-annual-assessment-time-and-cost

In 2021, CARB adopted Heavy-Duty Engine and Vehicle Regulation (Omnibus Regulation), which is to drastically cut NOx from conventional HD engines. The new regulation reduces the current heavy-truck NOx standard from 0.20 grams per brake horsepower hour to 0.050 g/bhp-hr from 2024 to 2026, and to 0.020 g/bhp-hr in 2027. In late 2022, EPA adopted HD truck standards for tighter emission limits in two stages, starting in model year 2027. However, the U.S. EPA standard doesn't provide the same level of emission reductions as California's Omnibus rule. It is anticipated that additional action will be necessary to reduce emissions from HD trucks.

Electric / Hybrid Vehicle Technologies and Infrastructure

There has been more developments and attention on electric and hybrid vehicles due to a confluence of factors, including the highly successful commercial introductions of hybrid LD passenger vehicles, plug-in electric vehicles (PEVs), and battery electric vehicles (BEVs) by the major OEMs and increased public attention on global warming, approval of the CARB Advanced Clean Cars II regulation establishing an annual roadmap for 100% ZEV for new LD and light trucks by 2035. This regulation codifies the LD vehicle goals in California Governor Newsom's Executive Order N-79-20.

According to the CEC[7], new LD ZEV sales in California are 342,888 in 2023 with cumulative sales of 1,742,801 vehicles. This includes annual LD ZEV sales of 291,649 BEVs, 48,327 PHEVs, and 2,912 FCEVs. Larger batteries and longer range continue to be the trend for LD BEVs with the Lucid Air Dream Performance with a 118 kWh battery and 520 mile U.S. EPA estimated range and the Tesla Model S with a 100 kWh battery and 405 mile U.S. EPA estimated range as two examples of these longer range LD BEVs.

Technology transfer to MD and HD applications has made significant progress, especially with commercialization of Class 6 - 8 BETs by the major OEMs as well as MD shuttle bus, delivery van, transit bus, and cargo handling equipment through freight handling and goods movement demonstration and deployment projects in the Basin. As with hydrogen and fuel cell technologies, South Coast AQMD is actively pursuing research, development and demonstration projects for MD and HD BETs and their commercialization. The Clean Fuels Program has also supported the development of ETs including BETs and FCETs. U.S. DOE funded the ZECT 1 project to develop and demonstrate BETs and plug-in hybrid electric trucks (PHETs): four BETs from TransPower, two BETs from US Hybrid, two series PHETs from TransPower, and three parallel PHETs from US Hybrid. As the models developed in ZECT I project have been improved, BETs have an all-electric range of up to 220-275 miles for the latest 2023 models and PHETs have a range of up to 250 miles. The ZECT 1 project gave birth to many other BET and hybrid truck projects including subsequent projects such as the GGRF ZEDT project, which demonstrated 44 battery electric and CNG and diesel hybrid electric drayage trucks at multiple California Ports. The ZEDT project included 25 BYD 866 BETs, 12 Peterbilt/Meritor/TransPower 579 BETs, two Kenworth CNG hybrid electric trucks based on their T680 daycab, three Volvo diesel plug-in hybrid electric trucks, and two Volvo VNR Electric BETs. More recently, the Clean Fuels Program co-funded large Daimler and Volvo BET projects. For the Daimler Innovation Fleet project, Daimler deployed 14 Class 8 eCascadia and six Class 6 eM2 trucks and installed seven DC fast charging stations at fleet locations in 2019. Volvo deployed 30 Class 8 BETs and installed Level 2, AC, 50 kW and 150 kw DC fast chargers, and solar/storage as part of their CARB GGRF Low Impact Green Heavy Transport Solutions (LIGHTS) in 2022. Daimler deployed two Class 6 and six Class 8 BETs for its Customer Experience project which will be completed in 2023. Daimler will be deploying 15 Class 6 and 20 Class 8 BETs and chargers for commercial fleet

[7] https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics/new-zev-sales. Accessed January 18, 2024.

distribution/delivery operations for its Zero Emission Electric Delivery Truck project which will be completed in 2024. CARB and CEC funding for the JETSI Pilot Project deployed 100 BETs and 350 kW DC fast chargers for two fleets, NFI and Schneider.

Battery and hybrid electric off-road and marine applications including battery electric yard tractors, forklifts, top handlers, RTG cranes, locomotives, ocean going vessels, and construction equipment are included in multiple demonstration projects to accelerate commercialization and deployment of these technologies. South Coast AQMD has demonstrated a battery electric excavator and wheel loader with Volvo Construction Equipment as part of a FY 18 U.S. EPA Targeted Airshed Grant award and is will demonstrate 1.5 ton and 2.5 ton asphalt compactors. South Coast AQMD is also demonstrating the first battery electric line haul locomotive deployed in California in partnership with U.S. EPA, BNSF, and Progress Rail. An electric drive diesel hybrid tugboat will be demonstrated by fleet operator Centerline Logistics Corporation with co-funding from POLB and CARB. These pilot demonstration and deployment projects are key to additional emission reductions from the off-road construction, locomotive, and marine sectors.

Fueling Infrastructure and Deployment (Natural Gas/Renewable Fuels)

A key element for increased use of alternative fueled vehicles and resulting widespread acceptance is the availability of the supporting refueling infrastructure. The refueling infrastructure for gasoline and diesel fuel is well established and accepted by the driving public. Alternative, clean fuels, such as alcohol-based fuels, propane, hydrogen, and even electricity, are much less available or accessible, whereas NG and renewable fuels have recently become more readily available and cost-effective. Nonetheless, to realize emissions reduction benefits, alternative fuel infrastructure, especially fuels from renewable feedstocks, must be developed in tandem with the growth in alternative fueled vehicles. While California appears to be on track to meet its Renewable Portfolio Standard targets of 33 percent by 2020 and 50 percent by 2030 as required by SB 350 (chaptered October 2015), the objectives of the South Coast AQMD are to expand the infrastructure to support zero and near-zero emission vehicles through the development, demonstration and installation of alternative fuel vehicle refueling technologies. However, this category is predominantly targeted at NG and renewable natural gas (RNG) infrastructure and deployment (electric and hydrogen fueling are included in their respective technology categories). The Clean Fuels Program will continue to examine opportunities where current incentive funding is either absent or insufficient.

Stationary Clean Fuel Technologies

Given the limited funding available to support low emission stationary source technology development, this area has historically been limited in scope. To gain the maximum air quality benefits in this category, higher polluting fossil fuel-fired electric power generation needs to be replaced with clean, renewable energy resources or other advanced zero and near zero-emission technologies, such as solar, energy storage, wind, geo-thermal energy, bio-mass conversion and stationary fuel cells. Although combustion sources are lumped together as stationary, the design and operating principles vary significantly and thus also the methods and technologies for control of their emissions. Included in the stationary category are boilers, heaters, gas turbines and reciprocating engines as well as microgrids and some renewables. The key technologies for this category focus on using advanced combustion processes, development of catalytic add-on controls, alternative fuels and technologies and stationary fuel cells in novel applications.

Although stationary source NOx emissions are small compared to mobile sources in the Basin, there are applications where cleaner fuel technologies or processes can be applied to reduce NOx, VOC and PM emissions. Recent demonstration projects funded in part by the South Coast AQMD include a local sanitation district retrofitting an existing biogas engine with a digester gas cleanup system and catalytic exhaust emission control. The retrofit system resulted in significant reductions in NOx, VOC and carbon monoxide (CO) emissions. This project demonstrated that cleaner, more robust renewable distributed generation technologies exist that not only improve air quality but enhance power quality and reduce electricity distribution congestion. Another ongoing demonstration project consists of retrofitting a low NOx ceramic burner on an oil heater without the use of reagents, such as ammonia nor urea, which is anticipated to achieve selective catalytic reduction (SCR) NOx emissions or lower. SCR requires the injection of ammonia or urea that is reacted over a catalyst bed to reduce the NOx formed during the combustion process. Challenges arise if ammonia distribution within the flue gas or operating temperature is not optimal resulting in ammonia emissions leaving the SCR in a process referred to as "ammonia slip". The ammonia slip may also lead to the formation of particulate matter in the form of ammonium sulfates. Based on the successful deployment of this project, further emission reductions may be achieved by other combustion sources (such as boilers) by the continued development of specialized low NOx burners without the use of reagents.

Health Impacts, Fuel and Emissions Studies

The monitoring of pollutants in the Basin is extremely important, especially when focused on (1) a sector of the emissions inventory (to identify the responsible technology) or (2) exposure to pollution (to assess potential health risks). Several studies indicate that areas with high levels of air pollution can produce irreversible damage to children's lungs. This information highlights the need for further emissions and health studies to identify the emissions from high polluting sectors as well as the health effects resulting from these technologies. As we transition to new fuels and forms of transportation, it is important to understand the impacts that changing fuel composition will have on exhaust emissions and in turn on ambient air quality. This area focuses on exhaust emissions studies, with a focus on NOx and PM2.5 emissions and a detailed review of other potential toxic tailpipe emissions, for alternative fuel and diesel engines. These types of in-use emissions studies have found significantly higher emissions than certification values for HD diesel engines, depending on the duty-cycle. South Coast AQMD recently completed Multiple Air Toxics Exposure Study V (MATES V), a three-year in-use emissions study of 200 next-generation technology HD vehicles in the Basin. MATES V is aimed at understanding the activity pattern of different vocations and real-world emissions emitted from different technologies. Key findings of the MATES V study showed a 54 percent decline in overall multi-pathway cancer risk from MATES IV and diesel PM remains the main risk driver contributing to 67 percent of the overall multi-pathway cancer risk based on population-weighted estimates. Cancer risk decreased at every monitoring station in the South Coast Air Basin with the highest risk at the Inland Valley San Bernardino monitoring station. Communities adjacent to the Ports are in the top 96th percentage of air toxics cancer risk. Other studies launched in 2020 will evaluate emissions produced using alternative diesel blends in off-road HD engines, assess emissions impact of hydrogen-natural gas blends on near-zero emission HD NG engines as well as evaluating emissions produced using higher blend ethanol in LD gasoline vehicles. MATES VI is currently underway and will expand on prior MATES studies by including measurements at two near-road sites, expansion of measurements to the Coachella Valley, source apportionment study to capture air toxic sources, ethylene oxide measurements and risk analysis, improvements to the emission inventory and air quality model, and initial evaluation of brake and tire wear contribution to PM.

Emissions Control Technologies

This broad category refers to technologies that could be deployed on existing mobile sources, aircraft, locomotives, marine vessels, farm and construction equipment, cargo handling equipment, industrial equipment, and utility and lawn-and-garden equipment. The in-use fleet comprises most emissions, especially older vehicles and non-road sources, which are typically uncontrolled and unregulated, or controlled to a much lesser extent than on-road vehicles. The authority to develop and implement regulations for retrofit on-road and off-road mobile sources lies primarily with U.S. EPA and CARB. Both agencies are currently planning research efforts for off-road mobile sources.

Low emission and clean fuel technologies that appear promising for on-road mobile sources should be effective at reducing emissions for off-road applications. For example, immediate benefits are possible from particulate traps and SCR technologies that have been developed for on-road diesel applications although retrofits are often hampered by physical size and visibility constraints. Clean fuels such as NG, propane, hydrogen and hydrogen-natural gas mixtures may also provide an effective option to reduce emissions from some off-road applications, even though alternative fuel engine offerings are limited in this space, but retrofits such as dual-fuel conversions are possible and need to be demonstrated. Reformulated gasoline, ethanol and alternative diesel fuels, such as biodiesel and gas-to-liquid (GTL), also show promise when used in conjunction with advanced emissions controls and new engine technologies. Emissions assessments are important in such projects as one technology to reduce one contaminant can increase another.

Technology Assessment and Transfer / Outreach

Since the value of the Clean Fuels Program depends on the deployment and adoption of the demonstrated technologies, technology assessment and transfer efforts are an essential part of the Clean Fuels Program. This core area encompasses assessment of advanced technologies, including retaining outside technical assistance as needed, efforts to expedite implementation of low emission and clean fuels technologies, and coordination of these activities with other organizations, including networking opportunities seeking outside funding. Assembly Bill (AB) 617[8], which requires reduced exposure to communities most impacted by air pollution, required TAO to carry out additional outreach in CY 2023 to AB 617 communities regarding available zero and near-zero emission technologies as well as the incentives to accelerate those cleaner technologies into their communities. TAO staff also provide input as part of working groups, such as the San Pedro Bay Ports Technology Advancement Program, Metro I-710 South Corridor Task Force, Electric Power Research Institute (EPRI) eTRUC technical advisory committee, CALSTART EnergIIZE Funding Advisory Committee, 21st Century Truck Partnership Charging and Infrastructure Work Group, LA 28 Olympic and Paralympic Games Sustainability Working Group, and Los Angeles Cleantech Incubator projects. Technology transfer efforts also include support for various clean fuel technology incentive programs (i.e., AB 617 CAPP, Carl Moyer Program, Proposition 1B-Goods Movement, etc.). Furthermore, community and stakeholder outreach has been included in grant proposals and funded projects administered by the Clean Fuels Program. Thus, the other spectrum of this core technology is information dissemination to educate and promote awareness of the public and end users. TAO staffed information booths to answer questions from the general public and provided speakers to participate on panels on zero and near-zero emission technologies at events, such as the 2023 ACT Conference and Expo, 2023 Portable Emission Measurement Systems Conference, 33rd Real World Emissions Workshop, California Hydrogen Leadership Summit, 16th Annual VerdeXchange Conference, Driving Mobility 10, 17th Annual Energy Independence Summit, SoCal Electrified Drive Event at the Orange County Auto Show, Asilomar

[8] https://ww2.arb.ca.gov/our-work/programs/community-air-protection-program/about

Conference on Transportation and Energy, Clean Mobility Forum and 2023 CoMotion LA. While South Coast AQMD's Legislative, Public Affairs & Media Office oversees and carries out such education and awareness efforts on behalf of the entire agency, TAO cosponsors and occasionally hosts various technology-related events to complement their efforts (see page 30 for a description of the technology assessment and transfer contracts executed in CY 2023 as well as a listing of the 18 conferences, workshops and events funded in CY 2023. Throughout the year, staff also participates in programmatic outreach for TAO incentive programs, including the AB 617 CAPP, Carl Moyer, Proposition 1B-Goods Movement, Volkswagen Mitigation, Replace Your Ride, U.S. EPA funded Commercial Electric Lawn and Garden Incentive and Exchange, residential lawn mower and residential EV charger rebate programs.

CLEAN FUELS PROGRAM

Barriers, Scope and Impact

Overcoming Barriers

Commercialization and implementation of advanced technologies come with a variety of challenges and barriers. A combination of real-world demonstrations, education, outreach and regulatory impetus and incentives is necessary to bring new, clean technologies to market. To reap the maximum emissions benefits from any technology, widespread deployment and user acceptance must occur. The product manufacturers must overcome technical and market barriers to ensure a competitive and sustainable business. Barriers include project-specific issues as well as general technology concerns.

Technology Implementation Barriers

- Viable commercialization path
- Technology price/performance parity with convention technology
- Consumer acceptance
- Fuel availability/convenience issues
- Certification, safety and regulatory barriers
- Quantifying emissions benefits
- Sustainability of market and technology
- Supporting infrastructure

Project-Specific Issues

- Identifying committed demonstration sites
- Overall project cost and cost-share using public monies
- Securing charging or fuel infrastructure
- Identifying and resolving real and perceived safety issues
- Quantifying actual emissions benefits
- Viability of technology providers

Other barriers include reduced or shrinking research budgets, infrastructure and energy uncertainties and risks, sensitivity to multi-media environmental impacts and the need to find balance between environmental needs and economic constraints. South Coast AQMD seeks to address these barriers by establishing relationships through unique public-private partnerships with key stakeholders; e.g., industry, end-users and other government agencies with a stake in developing clean technologies. Partnerships that involve all key stakeholders are essential to address these challenges in bringing advanced technologies from development to commercialization.

Each of these stakeholders and partners contributes more than just funding. Industry can contribute technology production expertise as well as the experience required for compatibility with process operations. Academic and research institutes bring current technology knowledge and testing proficiency. Governmental and regulatory agencies can provide guidance in identifying sources with the greatest potential for emissions reductions, assistance in permitting and compliance issues, coordinating of infrastructure needs, facilitation of standards and outreach. There is considerable synergy in developing technologies that address multiple goals of public and private agencies regarding environment, energy and transportation.

Scope and Benefits of the Clean Fuels Program

Since the time needed to overcome barriers can be long and the costs high, manufacturers and end-users find it challenging to undertake the risks in developing advanced technologies prior to commercialization. The Clean Fuels Program accelerates commercialization of these technologies by co-funding research, development, demonstration and deployment projects to share the risk of emerging technologies with technology developers and eventual users.

Figure 6 below provides a conceptual design of the wide scope of the Clean Fuels Program. As mentioned in the Core Technologies section, various stages of technology projects are funded not only to provide a portfolio of emissions technologies but to achieve emission reductions in the near-term and long-term horizon. The Clean Fuels Program funds projects in the Technology Readiness Level ranging between 3-8.

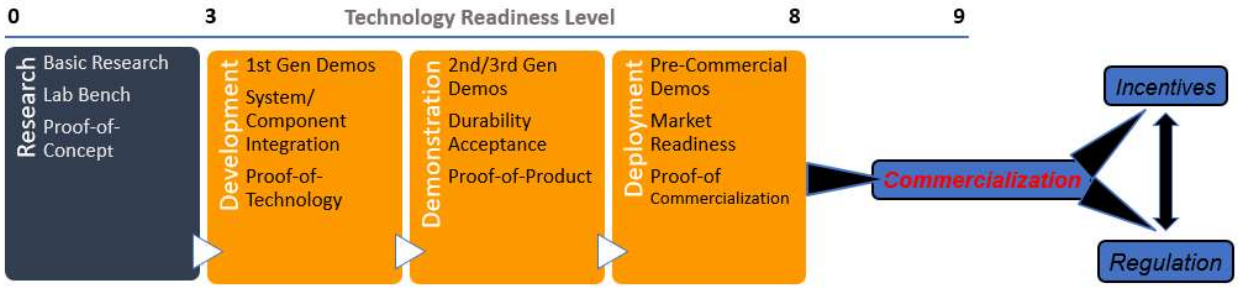


Figure 6: Stages of Clean Fuels Program Projects

Due to the nature of these advanced technology R D[3] projects, benefits are difficult to quantify since their full emissions reduction potential may not be realized until sometime in the future, or not at all if displaced by superior technologies. Nevertheless, a good indication of the impacts and benefits of the Clean Fuels Program overall are provided by this selective list of sponsored projects that have resulted in commercialized products or helped to accelerate advanced technologies.

➢Near-zero NOx Engine Development and Demonstrations for HD Vehicles

- CWI: low-NOx NG ISN- G 8.9L and 12L engines (0.2 & 0.02 g/bhp-hr);
- Southwest Research Institute (SwRI) project to develop a near-zero NOx HD diesel engine;
- Kenworth CNG Hybrid Electric Drayage Truck project;
- DOE ZECT II project – Kenworth developed one fuel cell truck & one CNG hybrid truck;
- CARB GGRF project – Kenworth developed advanced CNG hybrid truck by improving ZECT II CNG hybrid; and
- US Hybrid NZE Plug-In Hybrid demonstration with DOE/NREL/CEC.

➢Hydrogen Fuel Cell Development and Demonstration Projects

- Kenworth Fuel Cell Range Extended Electric Drayage Truck project;
- SunLine Transit Agency Advanced Fuel Cell Bus projects;
- UPS demonstration of fuel cell delivery trucks;
- Kenworth, TransPower, US Hybrid, Cummins developed and demonstrated 6 fuel cell drayage trucks under ZECT II project; and

- Hyundai's Class 8 fuel cell truck under development (Hyundai Exient)

➢ Electric and Hybrid Vehicle Development and Demonstration Projects

- Innovation Fleet – Daimler Class 6 and 8 BETs with Penske and NFI;
- Daimler Zero Emission BET Delivery Truck Project – Daimler Class 6 and 8 BETs;
- Volvo LIGHTS – Volvo Class 8 BET deployment with TEC Fontana, Dependable Highway Express (DHE), NFI, and 11 additional fleets;
- Volvo Switch-On – Volvo Class 8 BET deployment with eight fleets;
- JETSI: Daimler and Volvo Class 8 BET large scale deployment with NFI and Schneider;
- TransPower/US Hybrid HD BETs and yard hostlers; and
- CARB GGRF ZEDT: 44 Class 8 BET, CNG hybrid, and diesel hybrid electric truck demonstration including 25 BYD BETs, 12 Peterbilt/Meritor/TransPower BETs, 2 Kenworth CNG hybrid electric, 2 Volvo diesel hybrid electric and 2 Volvo BETs;

➢ Aftertreatment Technologies for HD Vehicles

- Johnson Matthey and Engelhard trap demonstrations on buses and construction equipment;
- Johnson Matthey SCRT and SCCRT NOx and PM reduction control devices on HD on-road trucks; and
- SwRI development of aftertreatment for HD diesel engines

South Coast AQMD played a leading or major role in the development of these technologies, but their benefits could not have been achieved without all stakeholders (i.e., manufacturer, end-users and government) working collectively to overcome the technology, market and project-specific barriers encountered at every stage of the RD^3 process.

Strategy and Impact

In addition to the feedback and input detailed in Program Review, South Coast AQMD actively seeks additional partners for its program through participation in various working groups, committees and task forces. This participation has resulted in coordination of the Clean Fuels Program with state and federal government organizations, including CARB, CEC, U.S. EPA and DOE/DOT and several national laboratories. Coordination also includes the AB 2766 Discretionary Fund Program administered by the Mobile Source Air Pollution Reduction Review Committee (MSRC), various local air districts including but not limited to Bay Area AQMD, Sacramento Metropolitan AQMD, San Diego Air Pollution Control District (APCD) and San Joaquin Valley Air Pollution Control District (SJVAPCD), as well as the National Association of Fleet Administrators (NAFA), major local transit districts, local gas and electric utilities, national laboratories, San Pedro Bay Ports and several universities with research facilities, including but not limited to Universities of California Berkeley, Davis, Irvine, Los Angeles and Riverside, and West Virginia University. The list of organizations with which South Coast AQMD coordinates research and development activities also includes organizations specified in H&SC Section 40448.5.1(a)(2).

In addition, South Coast AQMD holds periodic meetings with several organizations specifically to review and coordinate program and project plans. For example, South Coast AQMD staff meets with CARB staff to review research and development plans, discuss project areas of mutual interest, avoid duplicative efforts and identify potential opportunities for cost-sharing. Periodic meetings are also held with industry-oriented research and development organizations, including but not limited to Hydrogen Fuel Cell Partnership, California Stationary Fuel Cell Collaborative, EPRI, Veloz, Los Angeles Cleantech Incubator Regional Transportation Partnership, and West Coast Collaborative. The coordination efforts with these various

stakeholders have resulted in several cosponsored projects.

Descriptions of key contracts executed in CY 2023 are provided in the next section of this report. It is noteworthy that most projects are cosponsored by various funding organizations and include active OEM involvement. Such partnerships are essential to address commercialization barriers and expedite implementation of advanced technologies. Table 2 below lists major funding agency partners and manufacturers actively involved in South Coast AQMD projects for this reporting period. It is important to note that, although not listed, there are many other technology developers, small manufacturers and project partners who make important contributions critical to the success of the Clean Fuels Program. These partners are identified in the more detailed 2023 Project Summaries by Core Technologies contained within this report, as well as Table 5 which lists federal, state and local funding awarded to South Coast AQMD in CY 2023 for RD[3] projects (which will likely result in executed project contracts in 2024).

Table 2: South Coast AQMD Major Funding Partners in CY 2023

Research Funding Organizations	**Local Entities & Utilities**
California Air Resources Board	Arrowhead Regional Medical Center
California Energy Commission	San Bernardino County
Department of Energy	San Diego Gas & Electric Company
US Environmental Protection Agency	Southern California Edison Company
Fleet Providers	**Major Manufacturers/Technology Providers**
SunLine Transit Agency	RockeTruck Inc

The following two subsections broadly address South Coast AQMD's impact and benefits by describing specific accomplishments including commercial or near-commercial products supported by the Clean Fuels Program in CY 2023. Such examples are provided in the following sections on TAO Research, Development and Demonstration projects and Technology Deployment and Commercialization efforts.

Research, Development and Demonstration

Important examples of the impact of South Coast AQMD research and development coordination efforts in 2023 include: (a) JETSI: Deploy 100 Electric Trucks at Scale and (b) Commercial Advancement of Mobile Fuel Cells.

- **JETSI: Deploy 100 Electric Trucks at Scale**

The JETSI project received $27 million in CARB and CEC funding in April 2021 to deploy 100 Class 8 Daimler and Volvo BETs at two fleets (50 at NFI and 50 at Schneider), located in overburdened communities in Ontario and South El Monte. South Coast AQMD led a regional collaborative with the MSRC, Southern California Edison (SCE), Port of Long Beach (POLB), and Port of Los Angeles (POLA), which collectively provided $21.4 million in funding. Fleets NFI and Schneider are providing $25.4 million in match share.

JETSI will significantly advance market penetration of Class 8 BETs through at-scale manufacturing

production by Daimler and Volvo. To support the BETs, both fleets will deploy HD charging infrastructure. NFI will also deploy distributed energy resource (DER) technologies including solar and battery energy storage, as well as build a BET maintenance shop at its site. The 100 BETs will operate almost solely through overburdened communities, including several designated under the AB 617 Community Air Protection Program. JETSI will result in 8,200 metric tons of GHG reductions, 5 weighted tons of criteria pollutants annually, and 5.5 million gallons of diesel fuel displaced over 8 years.

Schneider Deployment

Schneider completed its deployment of 50 Daimler Class 8 BETs and sixteen 350 kW direct current (DC) fast chargers with standardized CCS1 connectors in June 2023. This deployment will result in 2.6 tons of weighted criteria emission reductions and 4 metric tons of GHG reductions. Daimler truck specifications for Schneider are similar to NFI. These trucks are shown in Figure 7.

Figure 7: Schneider Deployed 50 Daimler (Freightliner) Class 8 BETs at its South El Monte Site

To support the large-scale truck deployment, Schneider worked closely with Daimler to install sixteen 350kW DC fast chargers manufactured by Power Electronics. Daimler did extensive testing and integration work with Power Electronics at its research and development facility in Portland, Oregon, prior to this deployment. Charging infrastructure is shown in Figure 8.

Figure 8: Schneider Deployed Sixteen 350 kW DC Fast Chargers Manufactured by Power Electronics

Extensive coordination with SCE was required, which provided match funding through its Charge Ready Transport (CRT) program. SCE's match funding upgraded power to the Schneider site behind the meter, as well as provided an incentive to Schneider for a portion of hardware and installation costs towards make-ready infrastructure under its SCE build option. Schneider went through a request for proposal (RFP) process to identify an engineering and design firm to handle permitting and to select an Electric Vehicle Infrastructure Training Program (EVITP) certified installer for construction. SCE and Schneider held a site kickoff meeting and coordinated construction with its respective crews.

After the media event and site turn-on in June 2023, some further work was done by Schneider staff to integrate communications between the vehicles and the chargers to optimize operations.

NFI Deployment

To date, NFI has deployed 30 Daimler and seven Volvo Class 8 BETs in drayage operations at its Ontario site. NFI deployed its charging infrastructure in two phases for a total of thirty-eight 350 kW DC fast charging ports with CCS1 connectors. Temporary power charging was completed in January 2024 with 10 charging ports utilizing low-voltage switchgear. The remaining charging ports will be completed in August 2024 after medium-voltage switchgear is delivered in May 2024.

Since NFI had an integrated project that included thirty-eight 350 kW fast chargers, 1 MW solar, and 4 MWh energy storage—SCE classified this project as primary service distribution because more than three service meters were required. This site also required a line extension, and NFI received an incentive under the CRT customer build option. Primary service distribution has additional requirements due to the high-voltage service coming to the site, including custom medium-voltage switchgear. This extended the construction timeline and costs significantly. Solar and storage are going through a separate interconnection process, and construction will commence after charging infrastructure is completed. Trucks, charging infrastructure, and the BET maintenance building are shown in Figure 9.

Figure 9: Partial Deployment of NFI Daimler Class 8 BETs and Charging Infrastructure

Data Collection and Analysis

Ricardo, Inc; CALSTART; and EPRI will collaborate on data collection and analysis for the BETs, infrastructure, and DER. Ricardo and CALSTART submitted an integrated data collection plan to CARB and CEC. Ricardo will perform data logging on a subset of baseline diesel trucks as well as deployed BETs for a 12- to 24-month data collection period, as well as conduct surveys, fleet/driver interviews, analyze data, and provide quarterly and final reports on data collection. CALSTART will focus on analyzing charging data and creating fleet case studies, including startup and final fleet deployment activities. EPRI will focus on charger performance and utilization analysis, development of a fleet reliability uptime dashboard, and analysis of grid impacts. University of California Riverside Center for Environmental Research and Technology (CE-CERT) will analyze data from the first 10 BETs at each fleet to evaluate energy savings potential from energy efficient routing software for BETs.

- **Commercial Advancement of Mobile Fuel Cells**

The RockeTruck Commercial Advancement of Mobile Fuel Cells (CAMFC) project builds on the Mobile Fuel Cell Generator (MFCG) project, which received $3 million in CEC funding in February 2022 to develop and demonstrate two mobile generators using hydrogen fuel cells. The first generator will be tested and demonstrated in San Diego County in collaboration with San Diego Gas & Electric Company (SDG&E), and the second will be tested and demonstrated in the Basin in collaboration with SCE. On August 20, 2023, the South Coast AQMD executed a contract with RockeTruck, providing $200,000 in additional funding to support improvements in the design of the second generator ("Generator #2"). The primary goal of these improvements will be to enhance the commercial viability of the MFCG system. An additional $1,005,567 in cost sharing is being provided by RockeTruck, augmented by contributions from the U.S. Department of Energy ($206,500); SDG&E ($100,000); SCE ($90,000); and battery supplier, Coulomb Solutions, Inc. ($15,000).

Each of the prototype MFCG systems (Generator #1 and Generator #2) will carry its own hydrogen fuel in cylindrical carbon fiber tanks, and at least one of the two MFCG systems will be equipped with sufficient hydrogen storage capacity to produce an average of 35kW of power for 48 hours. Each hydrogen fuel subsystem will be carried on a custom-designed trailer (Figure 10) that can be towed by a large pickup truck. The primary power source for each generator system will be an 80kW hydrogen automotive fuel cell provided by American Honda Motors. Each generator will be equipped with power converters capable of delivering single-phase 110V power and three-phase 208V power. With the addition of a transformer, 480V, three-phase output can be obtained. The fuel cell subsystem may be augmented with battery packs that will provide power to start the system and that can supplement the fuel cells to deliver higher power levels for brief periods. A proprietary fuel cell and energy management control system will optimize generator efficiency, maximize fuel cell life, and protect key components, such as fuel cells, batteries, and power electronics from excessive temperatures, voltage spikes, or current surges. For Generator #1, all the above components will be integrated onto a single trailer. For Generator #2, the hydrogen fuel subsystem may be installed onto its own separate trailer, with the fuel cell and balance of plant installed into the bed of the pickup truck used to tow the fuel subsystem trailer.

Figure 10: Custom Trailer Built to Carry First RockeTruck Mobile Fuel Cell Generator

The $206,500 contributed by the Department of Energy (DOE) to the MFCG project was provided by a Phase I Small Business Technology Transfer (STTR) grant that ran from July 2022 through March 2023. This increment of funding was used to develop a more compact MFCG concept which RockeTruck named the "MFCG Mini." In August 2023, the DOE awarded RockeTruck a Phase II STTR grant valued at $1,150,000 to design, build, and demonstrate a prototype of the Mini, which will be built in parallel with the second large generator being funded by the CEC and South Coast AQMD. RockeTruck now calls the larger generator the "MFCG Ultra."

System Specifications

The Mini is designed either to operate in a stand-alone mode (using a very small amount of hydrogen stored in one or two tanks carried in the pickup truck bed along with the fuel cell and balance of plant) or in a "dual" mode, where the Mini is operated in conjunction with the Ultra. In the dual mode, the pickup truck carrying the Mini tows a trailer carrying an Ultra fuel cell system, allowing the large amount of hydrogen stored on the Ultra trailer to feed two fuel cells – the "Mini" fuel cell in the pickup truck and the "Ultra" fuel cell on the trailer.

Table 3 lists planned MFCG specifications and compares these specs with those of comparably sized diesel and battery electric generator options. The first data column shows specs for the Mini while operating in its stand-alone mode. As indicated, power levels sustainable for extended periods (24 to 48 hours) are comparatively low, due to its limited hydrogen fuel capacity. The second data column shows that the Ultra, with a projected hydrogen storage capacity of 120kg, can sustain much higher power levels for these intervals. The third data column shows that when the Mini and Ultra are used together in the "dual mode," power capabilities are even higher.

Table 3: Mobile Fuel Cell Generator Specifications

System Attribute	MFCG Mini	MFCG Ultra	Dual Mode Mini+Ultra	Diesel	Battery-Electric
Power – 48-hour Continuous	N/A	35 kW	55 kW	100 kW	35 kW
Power – 24-hour Continuous	6 kW	80 kW	120 kW	100 kW	70 kW
Power – 1-hour Peak	80 kW	120 kW	180 kW	110 kW	1,000 kW
Fuel power conversion efficiency @ 35 kW	55-60%	55-60%	60-62%	32%	89.5%
CO_2 emissions (48h/35 kW)	0	0	0	952 kg	0
Noise	Negligible	Negligible	Negligible	65-85 dB(A)	Negligible
System weight (approximate, excluding trailer or pickup)	1,000 kg	5,500 kg	6,500 kg	1,600 kg	15,000 kg
Commercial Driver License Required?	No	Yes	Yes	Yes	Yes
Capital cost per kWh (200,000 kWh life)	$0.50	$1.12	$1.62	$2.10	$3.75

Project Benefits

This project will demonstrate a novel mobile generator concept combining hydrogen fuel cells with lithium-ion batteries to produce electricity for sustained periods with zero emissions and reduced noise, as compared with conventional fossil fuel-powered generators. This approach can meet backup power needs during wildfires and other local emergencies. It also can deliver sustainable power for remote, off-grid communities to help achieve more equitable energy outcomes and improve resiliency by providing a new, highly flexible and transportable distributed energy resource.

Public Safety: The MFCG will deliver backup power during wildfires and other emergencies, recharging cell phones and other critical devices and sustaining the operation of critical facilities such as hospitals and service stations. The Ultra will be able to power large facilities for 24 to 48 hours without refueling. The Mini will be able to power a smaller facility for up to 8 to 10 hours.

Lower Costs: As hydrogen fuel costs decline, the MFCG can approach the total cost of ownership (TCO) of diesel generators and operate for less than half the TCO of a battery-based generator. The MFCG Mini will be capable of meeting shorter duration needs at an even lower cost.

Environment Benefits: Each MFCG Ultra system is projected to reduce GHG emissions by ~31 tons per year while eliminating the use of diesel generators for backup and portable power.

Energy Security: The MFCG will ensure energy reliability and continuity of critical operations in regions that lose access to grid power during emergencies and in remote regions, including low-income communities that are permanently off-grid.

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CLEAN FUELS PROGRAM

2023 Funding & Financial Summary

The Clean Fuels Program supports clean fuels and technologies that appear to offer the most promise in reducing emissions, promoting energy diversity, and in the long-term, providing cost-effective alternatives to current technologies. To address the wide variety of pollution sources in the Basin and the need for reductions now and in the future, using revenue from a $1 motor vehicle registration fee (see Program Funding on page 7), South Coast AQMD seeks to fund a wide variety of projects to establish a diversified technology portfolio to proliferate choices with the potential for different commercial maturity timing. Given the evolving nature of technology and changing market conditions, such a representation is only a "snapshot-in-time," as reflected by the projects approved by the South Coast AQMD Board.

As projects are approved by the South Coast AQMD Governing Board and executed into contracts during the year, finances may change to reflect updated information provided during the contract negotiation process. As such, the following represents the status of the Clean Fuels Fund as of December 31, 2023.

Funding Commitments by Core Technologies

South Coast AQMD continued its successful leveraging of public funds with outside investment to support the development of advanced clean air technologies. During the period from January 1 through December 31, 2023, a total of 22 contracts/agreements, projects or studies that support clean fuels were executed or amended (affecting dollars), as shown in Table 4. The major technology areas summarized are listed in order of funding priority. The distribution of funds based on technology area is shown graphically in Figure 11. This wide array of technology support represents South Coast AQMD's commitment to researching, developing, demonstrating and deploying potential near-term and longer-term technology solutions.

The project commitments that were contracted or purchased for the 2023 reporting period are shown below with the total projected project costs:

- South Coast AQMD Clean Fuels Fund Contribution $1,415,766
- Total Cost of Clean Fuels Projects $16,914,339

Traditionally, every year, the South Coast AQMD Governing Board approves funds to be transferred to the General Fund Budget for Clean Fuels administration. However, starting with FY 2017, fund transfer from Clean Fuels Fund to the General Fund was handled through the annual budget process. When the Board approved South Coast AQMD's FY 2023-24 Budget on May 5, 2023, it included $1 million from Clean Fuels Fund recognized in TAO's budget for technical assistance, workshops, conferences, co-sponsorships and outreach activities, as well as postage, supplies and miscellaneous costs. Only the funds committed by December 31, 2023, are included within this report. Any portion of the Clean Fuels Fund not spent by the end of Fiscal Year 2023-24 ending June 30, 2024, will be returned to the Clean Fuels Fund.For Clean Fuels executed and amended contracts, projects and studies in 2023, the average South Coast AQMD contribution was leveraged with $13 of outside investment. The typical historical leverage amount is $4 for every $1 of the South Coast AQMD Clean Fuels Fund, but from 2016 to 2023 there were several significant contracts in funding and impact that should make tangible progress toward developing and commercializing clean transportation technologies.

During 2023, distribution of funds for South Coast AQMD executed contracts, purchases and contract amendments with additional funding for the Clean Fuels Program totaling approximately $1.4 million are

shown in Figure 11 below.

Additionally, South Coast AQMD continued to seek funding opportunities and was awarded an additional $94 million in CY 2023 for RD[3] projects as listed in Table 5. As of January 1, 2024, there were 64 open Clean Fuels Fund contracts. Appendix B lists these contracts by core technology.

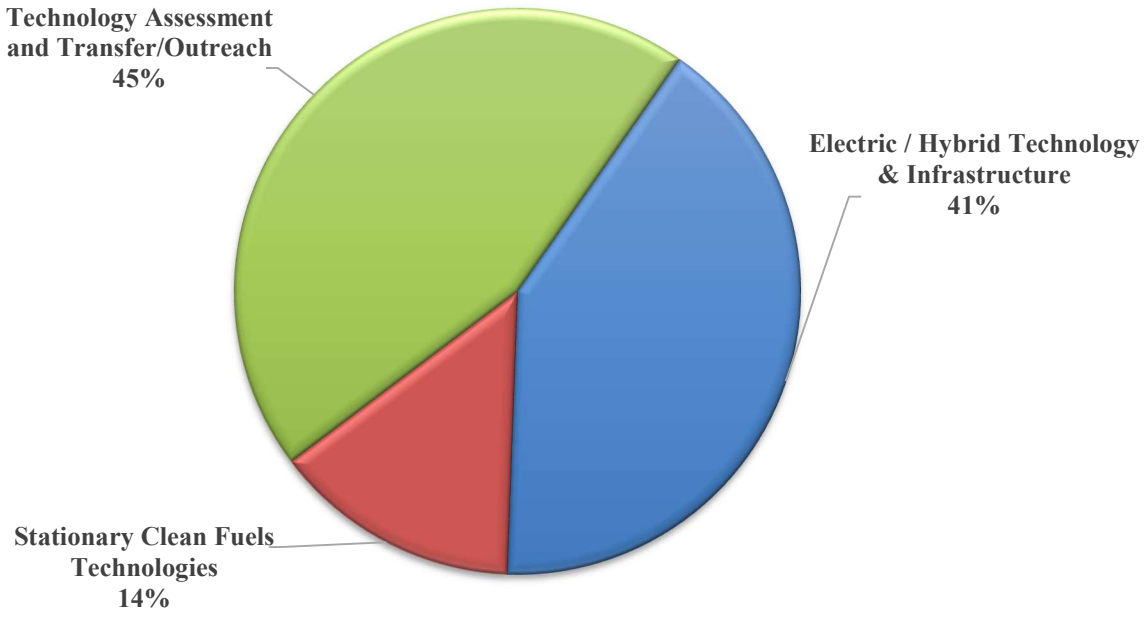

Figure 11: Distribution of Funds for Executed Clean Fuels Projects CY 2023 ($1.4M)

Review of Audit Findings

State law requires an annual financial audit after the closing of each South Coast AQMD fiscal year. The financial audit is performed by an independent Certified Public Accountant selected through a competitive bid process. For the fiscal year which ended June 30, 2023, South Coast AQMD engaged a new audit firm, Lance, Soll & Lunghard, LLP, to perform the Fiscal Year 2023 financial audit. The financial audit is ongoing and expected to be completed at the end of February 2024.

For the fiscal year which ended June 30, 2022, South Coast AQMD's Annual Comprehensive Financial Report was conducted by the firm of BCA Watson Rice, LLP. There were no adverse internal control weaknesses regarding South Coast AQMD financial statements, which include the Clean Fuels Program revenue and expenditures. BCA Watson Rice, LLP, gave South Coast AQMD an "unmodified opinion," the highest obtainable. Notably, South Coast AQMD has achieved this rating on all prior annual financial audits.

Project Funding Detail by Core Technologies

The 22 new and continuing contracts/agreements, projects and studies that received South Coast AQMD

funding in CY 2023 are summarized in Table 4, together with funding authorized by South Coast AQMD and project partners.

Table 4: Contracts Executed or Amended (w/$) between January 1 & December 31, 2023

Contract	Contractor	Project Title	Start Term	End Term	South Coast AQMD $	Project Total $
Technology Assessment and Transfer / Outreach						
Various	Various	Cosponsor 18 Conferences, Workshops & Events plus 3 Memberships	01/01/23	12/31/23	241,410	3,688,960
Direct Pay	Various	Advanced Technology Program Expenses	01/01/23	12/31/23	395,774	395,774
Electric / Hybrid Technologies and Infrastructure						
18129	Electric Power Research Institute	Versatile Plug-In Auxiliary Power System Demonstration	05/01/23	06/30/23	(20,000)	(20,000)
23072	CALSTART	Charging Infrastructure Data Collection, Fleet Case Studies, Analysis and Reporting for Deployment of 100 Class 8 Battery Electric Trucks	03/08/23	03/31/25	98,582	197,582
23103	San Bernardino County DBA Arrowhead Regional Medical Center	Deployment of Zero Emission Mobile Clinics	03/22/23	04/30/25	500,000	2,200,000
Stationary Clean Fuels Technologies						
24035	RockeTruck Inc	Development and Demonstration of Hydrogen Fuel Cell Mobile Power Generation System	08/20/23	06/30/25	200,000	4,617,067
Hydrogen / Mobile Fuel Cell Technologies and Infrastructure						
15150	Air Products and Chemicals Inc	Install/Upgrade Eight Hydrogen Fueling Stations throughout SCAG	10/10/14	04/09/24	(118,750)	(118,750)
21313	SunLine Transit Agency	Deployment of 6 Zero-Emission Fuel Cell Transit Buses	08/27/21	12/31/25	(1,215)	(1,215)
						$16,914,339

Table 5: Summary of Federal, State and Local Funding Awarded or Recognized in CY 2023

Awarding Entity or Program	Award (*) or Board Date	Purpose	Contractors	Award Total/ Fund
US EPA Clean Air Technology Grant	06/02/23	Medium-Duty Zero-Emission Electric Power Take-Off System Work Truck	Odyne Systems LLC	$500,000 Fund 17
US EPA Targeted Airshed Grant	06/02/23	Plug-in Hybrid Tugboat	Crowley Maritime Corporation	$10,000,000 Fund 83
US EPA Targeted Airshed Grant	06/02/23	Heavy-Duty Fuel Cell Trucks, and Battery Electric Asphalt Compactors	Various	$6,136,700 Fund 17
San Pedro Bay Ports	06/02/23	Ocean Going Vessel (OGV) Retrofit Project	Mediterranean Shipping Company	$600,000 Fund 83
California State Transportation Agency & DOE	12/01/23	Heavy-Duty Truck Charging, Fueling Infrastructure and Development of a Fuel Cell Locomotive	Prologis and Wabtec Corporation	$76,750,003 Fund 89
Table 5 provides a comprehensive summary of revenue awarded to South Coast AQMD during the reporting CY (2023) for TAO's RDD&D efforts which falls under the umbrella of the Clean Fuels Program, regardless of whether the revenue will be received into the Clean Fuels Program Fund (31) or the South Coast AQMD pass-through contract has been executed.				**$93,986,703**

Project Summaries by Core Technologies

The following summaries describe the contracts, projects and studies executed, or amended affecting dollars, in CY 2023. They are listed in the order found in Table 4 by category and contract number. As required by H&SC Section 40448.5.1(d), the following project summaries provide the project title; contractors and, if known at the time of writing, key subcontractors or project partners; South Coast AQMD cost-share, cosponsors and their respective contributions; contract term; and a description of the project.

Technology Assessment and Transfer / Outreach

- **Various: Cosponsor 18 Conferences, Workshops and Events plus 3 Memberships**

Contractor: Various	South Coast AQMD Cost-Share	$ 241,410
	Cosponsors:	
	Various	3,447,550
Term: 01/01/23 – 12/31/23	Total Cost:	$ 3,688,960

South Coast AQMD regularly participates in and hosts or cosponsors conferences, workshops and miscellaneous events. In CY 2023, South Coast AQMD provided funding for 18 conferences, workshops and events as follows: Clean Fuels Advisory Group Retreat in February and September; 17th Annual Energy Summit in February; Portable Emission Measurement Systems (PEMS) Conference in March; 33rd Real World Emissions Workshop in March; California Science Fair in April; ACT Conference and Expo in May; CALSTART 30th Anniversary Symposium in May; Southern California Chinese-American Environmental Protection Association Activities; California Hydrogen Leadership Summit in June; 16th Annual VerdeXchange Conference in May; Driving Mobility 10 Symposium in June; Move LA's Community Conversation in June; Asilomar Conference on Transportation and Energy in July; Women in Green – Inflation Reduction Act (IRA) Panel in September; Clean Mobility Forum in October; SoCal Electrified Drive Event in October; and CoMotion LA in November. Additionally, for 2023, three memberships were renewed for participation in CALSTART, a nonprofit organization working nationally and internationally with businesses and governments to develop clean, efficient transportation solutions; California Hydrogen Business Council (CHBC), a membership-based trade association, to educate the public and policymakers on the substantial benefits of hydrogen and to develop and advance policy positions that support the commercialization of hydrogen in the energy and transportation sectors to achieve California's climate, air quality, and decarbonization goals; and Hydrogen Fuel Cell Partnership (H2FCP, formerly California Fuel Cell Partnership), an industry/government collaboration aimed at expanding the market for FCEVs to create a cleaner, more energy-diverse future with no-compromise ZEVs.

- **Direct Pay: Advanced Technology Program Expenses**

Contractor: Various	South Coast AQMD Cost-Share	$ 395,774
Term: 01/01/23 – 12/31/23	Total Cost:	$ 395,774

South Coast AQMD TAO showcases new clean-fuel technologies to public and private organizations so that potential purchasers may familiarize themselves with available low-emission technologies and push the development of cleaner technologies. This direct pay covers the lease of three BEVs for three years,

purchase of two ZEVs, removal of decommissioned CNG equipment and various miscellaneous program expenses incurred in 2023.

Electric / Hybrid Technologies and Infrastructure

- **18129: Versatile Plug-In Auxiliary Power System Demonstration**

Contractor: Electric Power Research Institute	South Coast AQMD Cost-Share	$ (20,000)
Term: 06/28/18 – 06/30/23	Total Cost:	$ (20,000)

In December 2015, the Board awarded a contract to EPRI to cosponsor development and demonstration of a Versatile Plug-In Auxiliary (VAP) System. Based on the Phase I testing results, systems from alternative suppliers were evaluated and the scope of the project has expanded to include systems for portable power and portable DC fast charging. EPRI will use the previously approved cost-share for the second phase of the VAP System demonstration to evaluate the emissions and fuel usage benefits and impacts of electric auxiliary power in various on-board and stationary applications. Up to three units underwent baseline tests at Southern California Edison's EV Technical Center prior to field demonstration within South Coast AQMD. Procurement and testing of the VAP units took longer than expected, and the contract was extended multiple times. Due to COVID-19 and other operational issues, EPRI was only able to complete the data collection for six months for one VAP system. As such, EPRI requested revision to the statement of work to reflect the actual work completed. This change was also reflected in the payment schedule to reduce the contract amount to $105,000. Southern California Edison provided $128,000 in-kind cost share and $20,000 was provided by other partners.

- **23072: Charging Infrastructure Data Collection, Fleet Case Studies, Analysis and Reporting for Deployment of 100 Class 8 Battery Electric Trucks**

Contractor: CALSTART	South Coast AQMD Cost-Share	$ 98,582
	Cosponsors:	
	CEC *(received as pass-through funds into Fund 67)*	99,000
Term: 03/08/23 – 03/31/25	Total Cost:	$ 197,582

As part of JETSI, CARB funds the deployment of 100 commercial Class 8 BETs, while CEC funds charging infrastructure (EVSE), distributed energy resources (DER), charger infrastructure analysis, outreach with industry and community stakeholders, community and stakeholder outreach, ZEV workforce plan, data collection, and fleet case studies. CARB and CEC will also fund project administration and media/communications. CALSTART will focus on analyzing charging data and creating fleet case studies including startup and final fleet deployment activities. Ricardo (analyzing BET and baseline vehicle data) and CALSTART submitted an integrated data collection plan to CARB and CEC. Both entities will collect and analyze data for a 12 – 24 month data collection period, as well as conduct surveys, fleet/driver interviews, analysis, participate in monthly status calls, and provide quarterly and final reports on data collection.

- **23103: Deployment of Zero Emission Mobile Clinics**

Contractor: San Bernardino County DBA Arrowhead Regional Medical Center	South Coast AQMD Cost-Share	$ 500,000
	Cosponsors:	
	US EPA *(received as pass-through funds into Fund 17)*	500,000
	San Bernardino County	500,000
	Arrowhead Regional Medical Center	350,000
Term: 03/22/23 – 04/30/25	Total Cost:	$ 2,200,000

Arrowhead Regional Medical Center (ARMC) currently operates two mobile clinics using Class 6 gasoline-powered Recreational Vehicles (RVs). The RV clinical platforms referred to as Breathmobiles provide pediatric asthma management at no cost to school children residing within low-income communities within San Bernardino County's that experience high asthma-related hospitalizations. The two Breathmobiles routinely travel to 40 different school sites throughout San Bernardino County and during school hours clinical staff meet with school children and children from the surrounding areas. Under this project, ARMC will operate two new zero emission mobile clinics. One of the new clinics will replace an existing 2006 model year gasoline powered Breathmobile. The other will be a third mobile clinic that ARMC will use to provide service in the Fifth District of San Bernadino County, which includes the Rialto, Bloomington, Colton, San Bernardino City, Muscoy, and Devore areas. Both zero emission mobile clinics will have at least a 100-mile range and provide the clinics with over 5 hours of electrical power each. Eliminating the need to use a gasoline generator will benefit the sensitive receptors visiting the mobile clinics and reduce noise at the school sites. Both new mobile clinics are expected to be deployed by the end of 2024 and ARMC will upgrade its existing vehicle charging infrastructure to support the clinics. The development of zero emission mobile clinics provides transferable technology for other zero emission mobile clinic applications. Both new clinical vehicles will provide zero emission miles during transit and power the clinics without using a generator. Combined, the two new zero emission mobile clinics will prevent an additional 0.14 tons of NOx, 0.14 tons of hydrocarbons along with 4.8 tons of CO emissions annually.

Stationary Clean Fuels Technologies

- **24035: Development and Demonstration of Hydrogen Fuel Cell Mobile Power Generation System**

Contractor: RockeTruck Inc	South Coast AQMD Cost-Share	$ 200,000
	Cosponsors:	
	CEC	3,000,000
	RockeTruck Inc	1,005,567
	DOE	206,500
	SDG&E	100,000

	SCE	90,000
	Coulomb Solutions Inc	15,000
Term: 08/30/23 – 06/30/25	Total Cost:	$ 4,617,067

In late 2021, RockeTruck was awarded a $3 million grant from the CEC to develop and demonstrate an independent mobile clean energy alternative backup generation system. In mid-2022, RockeTruck was awarded another grant from the DOE to increase the peak power capability to produce a commercially viable mobile based fuel cell generator by the end of 2024. Under this Contract, RockeTruck will develop and demonstrate the second phase mobile based fuel cell generator. The proposed project leverages an existing mobile fuel cell generator project funded by CEC and DOE to develop a second higher powered system. Power output will be increased by using two Honda fuel cells and a 70 kWh commercial battery system provided by Coulomb Solutions, Inc. The power system upgrade will enable the second mobile fuel cell generator to maintain 35kW of continuous power generation for 48 hours with increased capabilities of 100 kW for up to 16 hours and 120kW peak output. The project also includes electrical upgrades that enable 480 volts three-phase power to provide high power charging of electric vehicles. The capability to charge vehicles will be demonstrated at the Hydrogen Research and Fueling Facility located at California State University, Los Angeles. Both SCE and SDG&E have agreed to participate in the testing of the mobile generator and support field demonstration within their service territories.

Hydrogen / Mobile Fuel Cell Technologies and Infrastructure

- **15150: Install/Upgrade Eight Hydrogen Fueling Stations**

Contractor: Air Products and Chemicals, Inc.	South Coast AQMD Cost-Share	$ (118,750)
Term: 10/10/14– 04/09/24	Total Cost:	$ (118,750)

Air Products was originally awarded funding for $1 million from South Coast AQMD to help cost-share this project with the CEC (PON-09-608) and offset higher than-anticipated initial equipment costs and investment for the production and distribution of hydrogen. Other funding was provided by CEC in the amount of $8,484,871 and by Air Products in the amount of $3,826,386 towards this $13,073,757 project. The hydrogen fueling stations are new (or upgraded), publicly accessible, next-generation (35 MPa and 70 MPa) located throughout Southern California, including the construction and upgrade of the existing station at South Coast AQMD headquarters in Diamond Bar. Six light-duty stations were built and operated under this contract. The West LA station was operated for three years as required, but the property is being redeveloped, the lease ended, and the equipment was removed. Air Products continues to operate the Diamond Bar, UC Irvine, Santa Monica, Beverly Blvd., and Lawndale stations. The Santa Clarita and Rancho Palos Verdes stations were removed from the statement work of this contract due to several operational issues. As such, CEC descoped these stations from the CEC Grant Agreement, and $237,500 ($118,750 per station) of Clean Fuels Program funds were de-obligated. The Diamond Bar station will continue operation through the end of the contract and a decrease of $118,750 in Clean Fuels Program funds has been applied to satisfy Air Product's obligation for the electricity costs incurred at the Diamond Bar station from commissioning in 2015 through April 2024. Total Clean Fuels Program funds towards this project are $644,325.

- **21313: Deployment of 6 Zero-Emission Fuel Cell Transit Buses**

Contractor: SunLine Transit Agency	South Coast AQMD Cost-Share	$ (1,215)
Term: 08/27/21 – 09/30/25	Total Cost:	$ (1,215)

SunLine Transit Agency provides transit services to the Coachella Valley, an ozone non-attainment area, including Eastern Coachella Valley, which is a Year 2 Community under South Coast AQMD's AB 617 Program. SunLine has recently commissioned their onsite renewable hydrogen fueling station at a 900 kg per day capacity, which is the largest onsite hydrogen generation station at any U.S. transit agency. SunLine's goal is to accelerate the transition to a fully zero emission bus fleet by 2035 to comply with CARB's Innovative Clean Transit (ICT) regulation. The newly upgraded hydrogen fueling station has a capacity for 30 buses, with a total of 21 buses now utilizing the station. Buses will operate on several routes in disadvantaged communities and replace older model year CNG transit buses. Initially 5 fuel cell buses were planned to be developed and deployed. SunLine subsequently received Hybrid and Zero-Emission Trucks and Bus Voucher Program (HVIP) discounts from CARB in 2021 to purchase the five buses. To utilize the remaining U.S. EPA funds, SunLine requested to deploy an additional fuel cell transit bus, which US EPA approved. As such, one additional fuel cell bus was added to the statement of work. Funding for this project has been provided by the US EPA in the amount of $5,750,000 to South Coast AQMD as pass-through funds into Fund 17; SunLine in the amount of $806,204; and South Coast AQMD in the amount of $203,706.

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CLEAN FUELS PROGRAM

Progress and Results in 2023

Key Projects Completed

Given the large number and diversity of emission sources contributing to the air quality problems in the Basin, there is no single technology or "silver bullet" that can solve all the region's problems. Only a portfolio of different technologies can successfully achieve the required emission reductions needed to meet the upcoming 2023 and 2032 air quality standards as well as the state's 2050 climate goals. Therefore, the South Coast AQMD continues to support a wide range of advanced technologies, addressing not only the diversity of emission sources, but also the time frame to commercialization of these technologies. Projects cofunded by the South Coast AQMD's Clean Fuels Program include emission reduction demonstrations for both mobile and stationary sources, although legislative requirements limit the use of available Clean Fuels funds primarily to on-road mobile sources. The projects funded not only expedite the development, demonstration and commercialization of zero and near-zero emission technologies and fuels, but also demonstrate the technical viability to technology providers, end-users and policymakers.

In the early years, the mobile source projects funded by the Clean Fuels Program targeted low emissions technology developments in automobiles, transit buses, medium- and HD trucks and off-road applications. Over the last several years, the focus has largely shifted to zero emission technologies for medium- and HD trucks, especially those in the goods movement and freight handling industry.

Table 8 provides a list of 33 projects and contracts completed in 2023. Summaries of the completed technical projects are included in Appendix C. Selected projects completed in 2023 which represent a range of key technologies from near-term to long-term are highlighted below: (a) Daimler Customer Experience BET Demonstration Project and (b) Continued Development of NG Engine Emissions and Efficiency Improvements.

- **Daimler Customer Experience BET Demonstration Project**

This project was built upon the already successful launch of the South Coast AQMD-supported Daimler Truck North America (DTNA) Innovation Fleet project (closed in 2022), where DTNA partnered with Penske Truck Leasing and NFI to demonstrate 20 prototype Class 6 and Class 8 BETs in the Basin. While the Innovation Fleet project had many benefits and lessons learned, only two HD fleet operators gained experience with this important technology. Thus, Daimler proposed the Customer Experience (CX) of Zero Emission Trucks and Mobile EV Infrastructure Project (CX Fleet project). DTNA was able to expand the access and experience with zero-emission BETs to a much larger number of its HD truck customers, many of whom represent some of the largest, high-profile fleet operations in North America.

In early 2022, DTNA entered into an agreement with the South Coast AQMD for $1,000,000 as a part of an overall $6,742,000 project budget for the construction and demonstration of eight commercial BETs and associated mobile HD truck capable DC charging infrastructure. Under the CX Project, DTNA agreed to design, develop, deliver, and demonstrate six Class 8 eCascadia and two Class 6 eM2 electric trucks. Partnering with some of the largest trucking companies in North America, these BETs were scheduled to be delivered to a select group of 12 to 18 DTNA customers for short-term, real-world demonstrations lasting between two to nine months between second quarter 2020 to second quarter 2022. Participating fleet operators included high-profile and large-fleet companies, such as Amazon, JB Hunt, Schneider, Ryder, Kroger (Ralphs), Knight-Swift, HUB Group, and several others. Two of these BETs were deployed in the Bay Area whereas the remaining six were deployed in the Basin, with short-term deployments as well in the Midwest and Canada. Below is a table of demonstration and miles accumulated at each fleet.

Figure 12: Class 6 and Class 8 BETs Demonstrated in the South Coast Air Basin

Table 6: BET Miles Accumulated during CX Demonstration

Fleet *Customer*	Vehicle Type	Serial Number	Start Date	End Date*	Total Months	Total Miles
J.B. Hunt	**eCascadia**	**ZZ0234**	**Jun. 2020**	**Mar. 2021**	**10**	**10,575.01**
Ryder	eCascadia	ZZ0230	Aug. 2020	Jan. 2021	6	9,220.49
Kroger	eCascadia	ZZ0232	Jul. 2020	Oct. 2020	4	8,009.26
Schneider	eCascadia	ZZ0233	Dec. 2020	Jun. 2021	7	14,586.27
Knight Swift	eCascadia	ZZ0208	Dec. 2020	Jun. 2021	7	4,259.07
May Trucking	eCascadia	ZZ0233	Jun. 2021	Jun. 2021	1	369.15
Southern Counties Express	eCascadia	ZZ0232	Nov. 2020	Feb. 2021	4	2,416.65
Ruan	eCascadia	ZZ0234	Dec. 2021	Dec. 2021	1	110.11
HUB	eCascadia	ZZ0234	Apr. 2021	Oct. 2021	7	17,068.23
Amazon	eCascadia	ZZ0232	Jul. 2021	Nov. 2021	5	1,218.47
TTSI	eCascadia	ZZ0232	May. 2022	May. 2022	1	620.88
Reyes Holdings	eCascadia	ZZ0233	Oct. 2021	Feb. 2022	5	4,077.23
Harbor Distributing	eCascadia	ZZ0233	Feb. 2022	Apr. 2022	3	2,846.73

Figure 13: ChargePoint CPE 250 Skid-Mounted Mobile Charger with Protective Cage

Charging of the CX Fleet trucks deployed through this project also provided a strategy for future market acceleration. The charging was accomplished via an innovative skid-mounted, HD electric DC charger. Allowing fleets to experience the technology provides them the opportunity to become familiar with charger functionalities and increase ease of use. This skid-mounted approach makes the medium HD BEV charger very portable and therefore easy to move and install at a site location, along with the trucks. This approach therefore minimizes the cost and time required to establish HD electric truck fueling infrastructure in a yard.

Furthermore, this approach allows easy access to charging capabilities in the event that installed charging infrastructure is down or inoperable. This also ensures consistent vehicle-charger software integration processes are not redundant and showcase a new and pioneering way by which medium HD electric fleet vehicle deployments can be facilitated in the early stages of market development.

The total fleet emissions reductions from this project are estimated below.

Table 7: Total Estimated Fleet Emissions Reductions from CX Demonstration

	CY2019	CY2020	CY2021
Total miles	30,432	49,063	4,859
Electricity Use (kWh)	58,205	93,882	9,494
Electricity Use (MJ)	209,538	337,974	34,178
Diesel Use (MJ)	1,047,690	1,689,868	170,981
GHG Emissions (gCO2e)	17,374,887	25,662,338	2,622,490
Avoided GHG Emissions (gCO2e)	87,865,549	114,084,917	14,543,487
NOx Emissions (g)	0	0	0
Avoided NOx Emissions (g)	**48,874**	**78,841**	**8,021**
PM2.5 Emissions (g)	0	0	0
Avoided PM2.5 Emissions (g)	**3,633**	**5,861**	**600**

- **Continued Development of NG Engine Emissions and Efficiency Improvements**

The South Coast AQMD has been supporting rapid deployment of near-zero NG engines for both medium-duty and HD vehicles since 2015 and supporting alternative fuel light-duty passenger vehicles since the early 2000s. With nearly two decades of operational experience in the Basin, NG technology is on its way toward full commercialization. However, there are ongoing concerns, such as those highlighted in the 2019

Feasibility Assessment for Drayage Trucks by Gladstein Neandross & Associates9, including the need for higher efficiency, more powerful NG engines.

To support these goals, the 2015 CEC NGV Research Roadmap[10] , the results of the DOE's most recent NGV stakeholder workshop in June 2017, and the input through the Natural Gas Vehicle Technology Forum, and other interactions with industry stakeholders were used as a basis for identifying key research, development, and demonstration needs. NREL is serving as program integrator for this Natural Gas Engine and Vehicle Research and Development Consortium project along with DOE, CEC and South Coast AQMD. All partnered to launch a research effort to increase efficiencies from NG medium- and HD engines and vehicles. These efforts will complement the DOE's Vehicle Technologies Office research efforts initiated in fiscal year (FY) 2017.

In September 2018, as part of this ongoing effort, NREL issued a request for proposal (RFP) offering funding of approximately $37 million for projects focusing on: (1) reducing the cost of NGVs, (2) increasing vehicle efficiency, and (3) advancing new innovative medium- and HD NG engine designs. Nine projects were selected for funding through this solicitation, four of which the South Coast AQMD helped cost share with $1.7 million from the Clean Fuels Fund because they aligned well with AQMP priorities to reduce NOx and PM emissions from transportation sources.

One of those awards was to Cummins Inc., the largest U.S. manufacturer of MD and HD NG engines. Cummins will address NG engine emissions and efficiency improvements by developing a natural gas-specific Tumble Charge Motion based combustion design utilizing high tumble charge motion and cooled exhaust gas recirculation. The technical targets of the project include:

- Develop an NG specific combustion system design that utilizes high tumble charge motion and cooled Exhaust Gas Recirculation (EGR) that builds upon a proven high cylinder pressure capable HD base engine platform in the 12 to 15L displacement range.
- Demonstrate cycle average brake thermal efficiency (BTE) 38-40 percent (>10 percent improvement over commercially available NG product on the ramped modal cycle supplemental emissions test [RMCSET]).
- Demonstrate peak BTE 41-43 percent (>10 percent improvement over commercially available product).
- Maintain 0.02 g/bhp-hr NOx capability.
- Demonstrate a diesel-like torque curve rating of 450-500 bhp and 2100-2500 Nm peak torque.
- Develop an engine integrated on a global platform to enable up to 20 percent system cost reduction.
- Confirm readiness for a TRL 6 demonstration with a prototype system.

This project kicked off in the fourth quarter 2019 and was completed in December 2023. In summary, this project resulted in the first purpose-designed, HD NG engine (compared to previous diesel engine-based NG engine designs) to achieve improved efficiency while maintaining ultra-low NOx emission levels with diesel like performance and reduced costs. The efficiency improvements expected for a combination of strategies will add 10-16 percent total improvements, as show below:

[9] https://www.gladstein.org/gna_whitepapers/2018-feasibility-assessment-for-drayage-trucks/

[10] http://www.energy.ca.gov/2015publications/CEC-500-2015- 091/CEC-500-2015-091- CMF.pdf

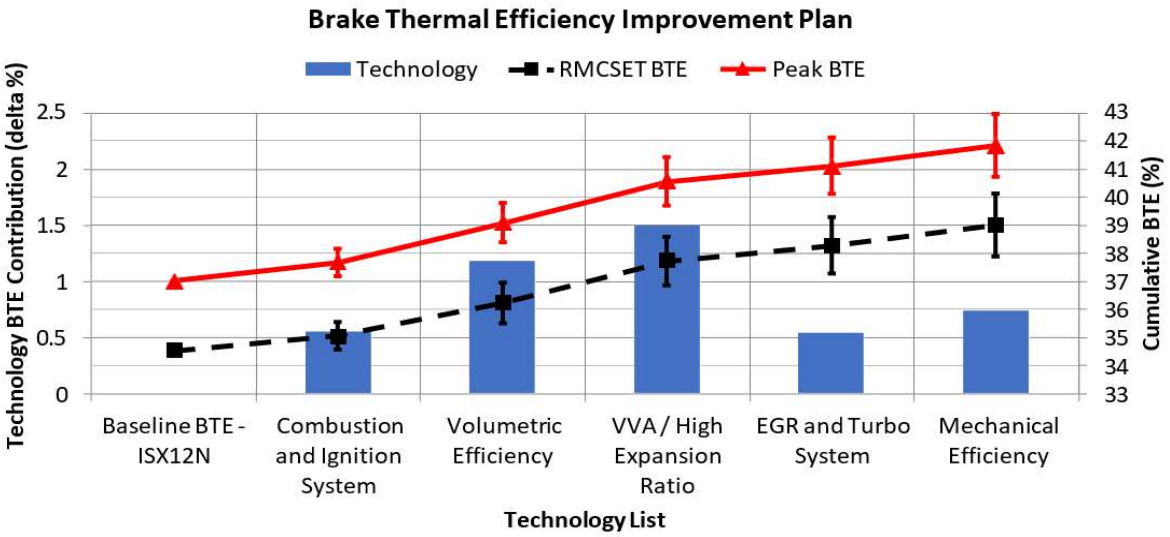

Figure 14: HD NG Engine Efficiency Gains Achieved

Overall, the engine met the project objectives by:

- Demonstrating 42 percent peak BTE against requirement of 41-43 percent. A 11 percent fuel consumption improvement over current ISX12N product.
- Demonstrating 40.2 percent steady state certification cycle average BTE. A 13 percent fuel consumption improvement over current ISX12N product.
- Demonstrating diesel like torque curve capability of 2500Nm@1000rpm and 512hp@1800rpm.
- Estimate showing up to 31 percent engine system cost reduction over current product ISX12N against requirement of 20 percent.
- Validating robust operation of new unique difficult technologies with over 1000 hrs of engine run time.
- Designing and developing a spark ignited (SI) suited pent-roof combustion system for improved closed cycle efficiency (CCE).
- Designing a HD NG engine that is ready to meet criteria pollutants and GHG emissions regulations well into the 2030's.
- Demonstrating capability to meet current product HD NG level emissions, including low NOx 0.02 g/hp-hr. The key federal test procedures (FTP) results, compared to the ISX12N engine, are show below:

FTP(g/bhp/hr)	2023 ISX12N		FEL/Std	15L NG	
	Cold FTP	Warm FTP	CHET	Cold FTP	Warm FTP
CO	2.21	0.73	15.5	0.66	0.48
NMHC	0.03	0	0.14	0.04	0.02
CH4	0.45	0.12	0.50	0.21	0.06
NOx	0.07	0	0.02	0.13	0.007
PM	0.0015	0.0044	0.01	NA	NA
CO2	544	495	531	396	386

Figure 15: HD NG Engine FTP Results

This project also led to the commercialization of the 15L NG engine for model year 2024, which is a key objective of this project. Cummins indicated the efficiency gains achieved in this project are expected to apply to future improvements for the new 15L NG engine.

Table 8: Projects Completed between January 1 & December 31, 2023

Contract	Contractor	Project Title	Date
Electric / Hybrid Electric Technologies and Infrastructure			
14184	Green Paradigm Consulting Inc	DC Fast Charging Network Provider	Jun 2023
17105	BYD Motors Inc	Development and Demonstration of up to 25 Class 8 Battery Electric Drayage Trucks	Oct 2023
17207	Peterbilt Motors	Development and Demonstration of up to 12 Class 8 Battery Electric Drayage Trucks	Oct 2023
18129	Electric Power Research Institute	Versatile Plug-In Auxiliary Power System Demonstration	Jun 2023
20097	Zeco Systems Inc DBA Greenlots	Operate, Maintain and Network EV Chargers	Feb 2023
20168†	OMNITRANS	Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers	Feb 2023
21077	Daimler Trucks North America LLC	Development and Demonstration of up to 8 Heavy-Duty Battery Electric Trucks and Transportable Fast-Charging (Customer Experience Project)	May 2023
Engine Systems / Technologies			
17353†	Odyne Systems LLC	Development and Demonstration of Medium-Heavy Duty (Class 5-7) Plug-In Hybrid Electric Vehicles for Work Truck Applications	Mar 2023
19439	Cummins Inc	Natural Gas Engine and Vehicles Research and Development – Natural Gas Specific Combustion Design	Aug 2023
20199	Agility Fuel Solutions LLC	Development of Near-Zero Natural Gas and Propane Conversion System for On-Road Medium-Duty Vehicles	Mar 2023
Fuel / Emission Studies			
21103	University of California Riverside	Perform Investigation Study of E15 Gasoline Fuel Effects	Mar 2023
Hydrogen / Mobile Fuel Cell Technologies and Infrastructure			
16025†	Center for Transportation and the Environment	Development and Demonstration of Fuel Cell Hybrid Electric Medium-Duty Trucks	Nov 2023
19313	Equilon Enterprises LLC DBA Shell Oil Products	Construct and Operate Renewable Hydrogen Refueling Station	Apr 2023
20244†	Cummins Electrified Power NA Inc	Demonstration of Fuel Cell Range-Extended Drayage Trucks	Dec 2023
Fueling Infrastructure and Deployment (NG / RNG)			
21140†	Inland Kenworth (US) Inc	SCAQMD Approved Participating Dealership in Truck Trade Down Program	Dec 2023
21142†	TEC of California Inc	SCAQMD Approved Participating Dealership in Truck Trade Down Program	Dec 2023

Table 8: Projects Completed between January 1 & December 31, 2023 (cont'd)

Contract	Contractor	Project Title	Date
Technology Assessment and Transfer / Outreach			
08210†	Sawyer Associates	Technical Assistance on Mobile Source Control Measures and Future Consultation on TAO Activities	Jul 2023
19227†	Gladstein, Neandross & Associates LLC	Technical Assistance with Alternative Fuels and Fueling Infrastructure, Emissions Analysis and On-Road Sources	Jan 2023
23104†	Compression Source Inc	Removal of CNG, Fuel Cell and Fast Charger Equipment from SCAQMD Headquarters	Mar 2023
23106†	Southern California Chinese American Environmental Protection Association	Cosponsor the Southern California Chinese-American Environmental Protection Association 2022 Activities	Jan 2023
23109†	Coordinating Research Council Inc	Cosponsor 33rd Real World Emissions Workshop	Jun 2023
23110†	University of California Riverside	Cosponsor the 2023 Portable Emissions Measurement Systems (PEMS) Conference	Aug 2023
23114†	University of California Irvine	Cosponsor ICEPAG 2022	Mar 2023
23122†	CALSTART	Cosponsor CALSTART's 30th Annual Symposium	Aug 2023
23125†	Transportation Energy Partners	Cosponsor the 17th Annual Energy Independence Summit 202	May 2023
23155†	Gladstein, Neandross & Associates LLC	Cosponsor the 2023 California Hydrogen Leadership Summit	Aug 2023
23156†	Gladstein, Neandross & Associates LLC	Cosponsor 2023 ACT Expo	Jul 2023
23157†	Community Partners for the VerdeXchange Institute Project	Cosponsor 16th Annual VerdeXchange Conference	Jul 2023
23160†	University of California Davis	Cosponsor Asilomar 2023 Conference on Transportation and Energy	Dec 2023
23178†	Community Partners	Cosponsor Move LA's Community Conversation 2023 Conference	Jun 2023
23227†	Sustain SoCal	Cosponsor the 2023 Driving Mobility 10	Aug 2023
24043†	United States Green Building Council – Los Angeles Chapter	Cosponsor the 2023 Women in Green – Inflation Reduction Act Panel	Nov 2023
24051†	Orange County Automobile Dealerships Association	Cosponsor the 2023 SoCal Electrified Ride Experience at OC Auto Show	Oct 2023

†Two-page summary reports (as provided in Appendix C) are not required for level-of-effort technical assistance contracts, leases or cosponsorships; or it was unavailable at time of printing this report.

CLEAN FUELS PROGRAM

2024 Plan Update

In 1988, SB 2297 (Rosenthal) was signed into law (Chapter 1546) establishing South Coast AQMD's Clean Fuels Program and reaffirming the existence of the TAO to administer the Clean Fuels Program. The funding source for the Clean Fuels Program is a $1 motor vehicle registration surcharge that was originally approved for a limited five-year period, but legislation eventually extended both the Program and surcharge indefinitely. The Clean Fuels Program has evolved over the years but continues to fund a broad array of technologies spanning near- and long-term implementation. Similarly, planning will remain an ongoing activity for the Clean Fuels Program, which must remain flexible to address evolving technologies as well capitalize on the latest progress in technologies, research areas and data.

Every year, South Coast AQMD re-evaluates the Clean Fuels Program to develop a Plan Update based on reassessment of clean fuel technologies and direction of the South Coast AQMD Board. This Plan Update for CY 2024 targets several projects to achieve near-term emission reductions needed for the South Coast to meet health-based NAAQS.

Overall Strategy

The overall strategy of TAO's Clean Fuels Program is based on emission reduction technology needs identified through the AQMP process and South Coast AQMD Board directives to protect the health of the approximately 18 million residents (nearly half the population of California) in the Basin. The 2022 AQMP is the long-term regional blueprint that relies on fair-share emission reductions from all jurisdictional levels (e.g., federal, state and local). The 2022 AQMP is composed of stationary and mobile source emission reductions from traditional regulatory control measures, incentive-based programs, projected co-benefits from climate change programs, mobile source strategies and reductions from federally regulated sources (e.g., aircraft, locomotives and ocean-going vessels). CARB's adopted 2022 SIP Strategy included a revised mobile source strategy required for the Basin to meet the 2015 8-hour ozone standard of 70 ppb by 2037. The adopted 2022 SIP Strategy for both mobile and stationary sources requires rapid deployment of zero emission technologies to achieve air quality targets.

The emission reductions and control measures In the 2022 AQMP rely on commercial adoption of a mix of currently available technologies as well as the expedited development and commercialization of clean fuel mobile and stationary advanced technologies in the Basin to achieve air quality standards. The 2022 AQMP identifies that 83 percent NOx emission reductions from the 2018 level and 67 percent additional reductions in 2037 beyond already adopted regulations and programs are necessary to meet the 2015 8-hour ozone standard by 2037. The majority of NOx reductions must come from mobile sources, including both on- and off-road sources. Notably, South Coast AQMD is currently one of only two regions in the nation designated as an extreme nonattainment area of the 2015 8-hour ozone NAAQS (the other region is California's San Joaquin Valley). The 2022 AQMP shows the need for economy-wide transition to zero emission technologies where feasible, and low NOx emission technologies in other applications.

Current federal and state efforts in developing regulations for on- and off-road vehicles and stationary equipment are expected to significantly reduce NOx emissions, but additional measures are needed to achieve 2031 and 2037 ozone attainment deadlines. To support fleet turnover, the Clean Fuels Program will emphasize on commercialization and deployment of zero emission HD trucks, like the large scale

deployment by JETSI Pilot Project and supporting zero emission infrastructure, and solar and energy storage.[11]

While zero emission technologies, the number of BETs and FCTs needed to meet the 2031 and 2037 ozone standards will be difficult to achieve. To enable widespread deployments of BETs and price reductions on these trucks from at scale production, several challenges must be addressed. These challenges include providing an easier process for fleets and independent owner operators to purchase BETs and overcoming obstacles with installing charging infrastructure, increasing grid capacity at their sites to coincide with truck deliveries, and managing charging and matching duty cycles with diesel trucks in drayage, short regional haul, and last mile freight applications. Projects, such as the JETSI 100 BET deployment and Electric Power Research Institute (EPRI) Electric Truck Research and Utilization Center (eTRUC) project to develop and demonstrate 1 MW chargers. The eTRUC project will implement two up to 1 MW charging sites while the JETSI project will focus on addressing the complexity of integrating 50 BETs at two fleets. On June 7, 2023, JETSI partner Schneider hosted a ribbon cutting event to celebrate the scaled deployment of BETs and charging infrastructure at their South El Monte intermodal site. The site features sixteen 350 kW dual-corded dispensers to allow Schneider to charge 32 trucks simultaneously. By year end, the site will support up to 100 BETs, including 50 funded through the JETSI project.

Within the Basin, other large fleets are purchasing BETs with near term delivery dates. Several fleets had trucks being delivered in 2022-2023 but unfortunately the installation of infrastructure lagged the delivery of the trucks. The difficulty of installing infrastructure to charge BETs is often a hindrance that many fleets have chosen not to tackle and simply have reverted to purchasing new diesel trucks. Even for large fleets who are interested in deploying charging, the lack of grid capacity and challenges in deploying solar, storage, or other technologies to offset grid demand makes it challenging to deploy infrastructure without significant lead times of 2-4 years, which does not coincide with the availability of truck and infrastructure incentives and truck delivery schedules. Public truck charging is needed for small fleets and owner operators who do not have the sites or funding to host their own charging. Additional technology solutions to provide energy generation which are not grid tied assets and the need to comply with multiple complex interconnection requirements are sorely needed to mitigate the frustrations with purchasing BETs. Unfortunately, in the Basin, the infrastructure for public truck charging is extremely limited[12]. South Coast AQMD, partnering with other entities, is seeking State and Federal funding opportunities to install HD public charging infrastructure. Meanwhile, South Coast AQMD had been strongly engaged in development and demonstration of low and zero emission alternative charging solutions (ACS). The availability of reliable ACS will help fill the void of infrastructure delays as well as provide a backup generation option during grid outages and public safety power shutoff events due to wildfires.

Today, diesel truck emissions are still the largest NOx emission category in the Basin. While CARB has the ACT, ACF, and HD Engine and Vehicle Omnibus regulations in place, there is still a need to tackle interstate truck emissions. On June 3, 2016, South Coast AQMD petitioned U.S. EPA to initiate rulemaking for a lower national NOx standard for on-road HD engines to achieve additional mobile source emission

[11] The project, known as Joint Electric Truck Scaling Initiative, or JETSI, will be one the largest commercial deployment of battery-electric trucks in North America to date, helping to significantly increase the number of zero-emission HD trucks available for goods movement while achieving necessary emission reductions. This is the first battery-electric truck project jointly financed by CARB and the CEC, and the largest investment of its kind.

[12] WattEV opened a public HD truck charging site at the Port of Long Beach in May 2023 which is capable of charging 26 trucks concurrently. It is currently equipped with 60 kW chargers but can be expanded to provide additional capacity. WattEV has other public HD charging sites in San Bernardino and Gardena that should be operational in December 2023.

reductions. The national NOx standard for on-road HD vehicles is estimated to result in 70 to 90 percent NOx emission reductions from this source category in 14 to 25 years, respectively. CARB estimates that 60 percent of total on-road HD vehicle miles traveled in the Basin are from vehicles purchased outside of California, which points to the need for a more stringent federal as well as state standard for on-road HD vehicles. U.S. EPA has acknowledged the need for additional NOx reductions through a harmonized and comprehensive national NOx reduction program for HD on-highway engines and vehicles. U.S. EPA adopted the final rule "Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards" in December 2022. Two additional EPA rules are under consideration, including the proposed Phase 3 HD GHG standards and the proposed LD and MD vehicle multi-pollutant standards for model year 2027. Both of these proposed rules include significant emphasis on large adoption of zero-emission LD, MD, and HD vehicles.

South Coast AQMD completed MATES V in August 2021 to update the emissions inventory of toxic air contaminants, as well as modeling to characterize risks, including measurements and analysis of ultrafine particle concentrations typically emitted or subsequently formed from vehicle exhaust. Findings from the MATES V report showed that air toxics cancer risk based on modeling data has decreased by 40 percent since 2015 MATES IV, with an average multi-pathway air toxics cancer risk at 454-in-a-million. The highest risk locations are at Los Angeles Airport (LAX), the San Pedro Bay Ports, and along major goods movement and transportation corridors. In MATES V, diesel PM is the largest contributor accounting for approximately 50 percent of the overall air toxics cancer risk. For the first time, chronic non-cancer risk was estimated with chronic hazard indices of 5 to 9 among the 10 stations in the MATES V study. MATES VI is in the planning stages with monitoring scheduled to start in mid 2025.

A key strategy of the Clean Fuels Program, which allows significant leveraging of Clean Fuels funding (historically $4 to every $1 of Clean Fuels funds), is its public-private partnerships with private industry, technology developers, academic institutions, research institutions and government agencies. Since 1988, the Clean Fuels Program provided more than $267.9 million toward projects nearing $1.7 billion. Leveraging of the Clean Fuels Fund is based on actual executed contracts and total project costs from the prior year's Clean Fuels Annual Report and Plan Update. In 1998, South Coast AQMD's Carl Moyer Program was launched. The two programs produce a unique synergy, with the Carl Moyer Program (and other subsequent incentive programs) providing the necessary funding to push market penetration of commercial technologies partially developed and demonstrated by the Clean Fuels Program. This synergy enables South Coast AQMD to act as a leader in technology development and commercialization efforts targeting reduction of criteria pollutants. Since the Carl Moyer Program began, South Coast AQMD has begun implementing other incentive programs (i.e., Volkswagen Mitigation, Proposition 1B-Goods Movement, and Community Air Protection Program), with cumulative funding of over $200 million in 2022. Since 2017, there has been cumulative funding of $370 million in AB 617 Community Air Protection Program (CAPP) incentives, of which $16.6 million will be used for zero emission trucks and charging infrastructure in the East Los Angeles/Boyle Heights/West Commerce, Southeast Los Angeles, San Bernardino/Muscoy, and Wilmington/Carson/West Long Beach[13]. The 2022 AQMP also included control measures to develop an indirect source regulation for the San Pedro Ports and strengthen fleet rules to take advantage of incentives to further accelerate emission reductions.

Despite several current California incentive programs to deploy cleaner technologies and offset the higher procurement costs of cleaner technologies, significant additional resources and technology development is

[13] Wilmington/Carson/West Long Beach will also provide incentive funding for near-zero emission trucks.

needed to achieve the NAAQS for this region. There are several key technologies that are discussed in detail later that will provide NOx and GHG co-benefits while requiring less vehicle purchase incentives.

The Clean Fuels Program has partnered with large OEMs, such as Daimler and Volvo to deploy HD BETs. These OEM partnerships allow the Clean Fuels Program to leverage their research, design, engineering, manufacturing, sales and service, and financial resources to move advanced technologies from the laboratories to the field and into customers' hands. The OEMs have the resources to develop advanced technology vehicles such as battery electric and fuel cell powertrains, manufacture in large quantities, and utilize their distribution networks to support sales across the state.

Figure 16 outlines a developmental progression for technology demonstration and deployment projects funded by the Clean Fuels Program and the relationship incentive programs administered by TAO play in that progression. The Clean Fuels Program funds various stages of technology projects, typically ranging from Technology Readiness Levels 3-8, to provide a portfolio of technology choices and achieve near-term and long-term emission reduction benefits.

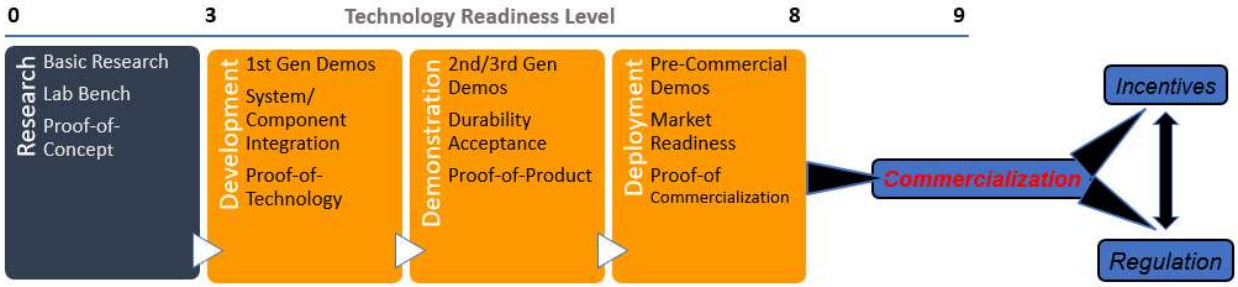

Figure 16: Stages of Clean Fuels Program Funding

Many technologies that address the Basin's needed NOx reductions align with the state's GHG reduction efforts. U.S. EPA (2023)[14] noted that the transportation sector contributed 28 percent of overall GHG emissions. Due to these co-benefits, South Coast AQMD has been successful in partnering with the state and public/private partnerships to leverage its Clean Fuels funding extensively.

Program and Funding Scope

This Draft 2024 Plan Update includes projects to research, develop, demonstrate and deploy a variety of advanced technologies, from near-term to long-term, that are intended to address the following challenges:

1) implementation of federal requirements, such as the more stringent federal 8-hour ozone standard of 70 ppb promulgated by U.S. EPA in late 2015;
2) implementation of new technology measures including accelerated development of technologies nearing commercialization and deployment of commercially ready technologies;
3) development of electric vehicle charging infrastructure and readiness of existing power grid; and development of alternative charging solutions;
4) necessity to improve hydrogen refueling station network reliability and availability, and the application of mobile hydrogen refueling where needed; and

[14] U.S. Greenhouse Gas Emissions and Sinks 1990-2021. 2023. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

5) continued development of near-term cost-effective approaches.

The overall scope of projects in the Draft 2024 Plan Update remains sufficiently flexible to address new technologies and control measures identified in the 2022 AQMP, dynamically evolving technologies, and new research and data. The latter includes findings from MATES V and emission inventories periodically updated by CARB.

Within the core technology areas defined later in this section, project objectives range from near term to long term. The Clean Fuels Program concentrates on supporting development, demonstration and technology commercialization and deployment efforts rather than fundamental research. The nature and typical time-to-product for Clean Fuels Program projects are described below, from near term to long term.

- Deployment or technology commercialization efforts focus on increasing utilization of clean technologies in conventional applications, promising immediate and growing emission reduction benefits. It is often difficult to transition users to non-traditional technologies or fuels due to higher upfront costs, limited refueling infrastructure, or required changes to user behavior, even if these technologies or fuels offer significant emission reduction benefits. In addition to the government's role to reduce risk by funding technology development and testing, it is also necessary to offset upfront purchase costs through incentives to accelerate the use of cleaner technologies. The increased use of these clean fuel technologies also depends on efforts to increase stakeholder confidence that these technologies are viable and cost-effective in the long term.
- Field demonstrations provide a controlled environment for manufacturers to gain real-world experience and address end-user issues that arise prior to the commercial introduction of technologies. Field demonstrations provide real-world evidence of performance to allay any concerns by early adopters as well as preliminary emissions reduction potential.
- Technology development projects are typically more advanced and require two or more years. Additionally, field demonstrations to gain long term verification of performance may also be needed prior to commercialization. Certification and commercialization would be expected to follow. Projects may involve the development of emerging technologies that are considered long-term and higher risk, but with significant emission reductions potential. Additionally, field demonstrations to gain long term verification of performance may also be needed prior to commercialization. In addition to field demonstrations, large scale pilot deployments are key to full certification and commercialization.

Core Technologies

The following technologies have been identified as having the greatest potential to enable the emission reductions needed to achieve the NAAQS and thus form the core of the Clean Fuels Program.

The goal is to fund viable projects in all categories. However, not all project categories will be funded in 2024 due to funding limitations, and the focus will remain on control measures identified in the 2022 AQMP, with consideration for availability of suitable projects. The project categories identified below are appropriate within the context of the current air quality challenges and opportunities for technology advancement.

Within these areas, there are significant opportunities for South Coast AQMD to leverage its funds with other funding partners to expedite the demonstration and deployment of clean technologies in the Basin. A

concerted effort is continually made to form public-private partnerships to maximize leveraging of Clean Fuels funds.

Several of the core technologies discussed below are synergistic. For example, a HD vehicle such as a transit bus or drayage truck, may utilize a hybrid electric drive train with a fuel cell operating on hydrogen fuel or an internal combustion engine (ICE) operating on an alternative fuel as a range extender. Components of the core hybrid electric system may overlap. Similarly, a hydrogen powered engine may utilize a NG HD vehicle that also combusts gaseous fuel and requires a compressed tank storage system; components of the similar combustion and fuel storage may overlap.

Priorities may shift during the year in keeping with the diverse and flexible technology portfolio approach or to leverage opportunities such as cost-sharing by the state or federal government or other entities. Priorities may also shift to address specific technology issues which affect residents within the South Coast AQMD's jurisdiction. For example, the AB 617 CAPP, signed by the Governor in 2017, implements emission reduction actions and provides incentive funding for designated AB 617 communities. The six AB 617 communities within the South Coast region designate funding priorities in their Community Emission Reduction Plans (CERPs). Additional flexibility will be needed to develop new strategies and technologies for those disadvantaged communities.

The following ten core technology areas are listed by current South Coast AQMD priorities based on the goals for 2024.

Zero Emission Infrastructure

Significant demonstration and commercialization efforts for zero emission infrastructure are funded by the Clean Fuels Program as well as other local, state and federal programs. Zero emission infrastructure has become an increasing focus of the Clean Fuels Program to support large scale demonstration and deployment of hydrogen fuel cell and battery electric vehicles and equipment. This stand-alone category was created in the 2023 Plan Update, separate from Hydrogen/Fuel Cell and Electric/Hybrid Technologies.

Hydrogen Infrastructure

With lead times on retail level hydrogen fueling stations requiring 18-36 months for permitting, construction and commissioning, plans for future stations need to be implemented. While coordination with the California Division of Measurement Standards (DMS) to establish standardized measurements for hydrogen fueling started in 2014, additional efforts to offer hydrogen for sale in higher volumes are still needed specifically with upcoming ZE vehicle and infrastructure policy deadlines on a national and state level. Moreover, CARB's Low Carbon Fuel Standard (LCFS) regulation provides incentives for producing and dispensing the low carbon intensity (CI) hydrogen for FCEVs, enabling station operators to remain solvent and cover part of their operational cost and consequently reducing the dollar per kilogram cost of hydrogen for consumers. Lastly, a deliberate and coordinated effort is necessary to ensure that hydrogen stations are developed with design flexibility to address specific location limitations, robust hydrogen supply, and fueling reliability matching those of existing gasoline and diesel fueling stations. The current network of hydrogen fueling stations to support the current number of LD FCEVs on the road and future MHD FCVs is insufficient, and supply of hydrogen and additional hydrogen production, specifically the carbon-neutral hydrogen, continue to be challenges that need to be addressed.

In 2019, the Clean Fuels Program awarded $1.2 million to Equilon (Shell) as part of the H2Freight project for a new 1,000 kg/day HD hydrogen fueling station using hydrogen produced by a new tri-generation fuel cell on POLB property leased by Toyota. The station was commissioned in July 2021 and Shell continues to operate and maintain this station to consumer including Toyota and other fleet operators that commit to use FCEVs. As part of the $83 million Shore-to-Store project led by the POLA, for which the Clean Fuels Program committed $1 million, Toyota and Kenworth deployed 10 Class 8 fuel cell trucks and Equilon (Shell) built two large capacity hydrogen fueling stations in Wilmington and Ontario. Kenworth leveraged the development on the fuel cell truck demonstrated in South Coast AQMD's ZECT 2 project and integrated Toyota's fuel cells into the Kenworth trucks. These fuel cell trucks are deployed at fleets including UPS, Total Transportation Services, Southern Counties Express, and Toyota Logistics Services at the Ports of Los Angeles and Port Hueneme, as well as other fleets in Riverside County. Most of the fuel cell trucks completed the demonstration phase. Also, the Ontario and Wilmington stations are commissioned and completed site acceptance testing by November 2022, moving to 24-hour unstaffed operations. South Coast AQMD continues to work with H2FCP to achieve a reliable hydrogen refueling network in California through demonstrating and developing standards, protocols, and green hydrogen production pathways.

New, ongoing, and recently completed hydrogen infrastructure projects include: 1) POLA Shore to Store project with deployment of two 400 kg/day hydrogen fueling stations in Wilmington and Ontario for HD fuel cell trucks and 2) retrofit of existing hydrogen infrastructure stations to accommodate HD fuel cell trucks by First Element to demonstration Hyundai Class 8 fuel cell trucks, and 3) Equilon (Shell) project to develop a new 1000 kg/day HD hydrogen fueling station in POLB.

There are numerous fuel cell applications for off-road equipment; however, one of the primary challenges is the lack of access to hydrogen fueling stations in these settings. Installing on-site hydrogen refueling infrastructure would be costly and impractical, particularly in land-constrained areas like port complexes. To address this issue, the development and demonstration of a fuel cell-powered mobile hydrogen refueler is proposed. This mobile refueler aims to provide the necessary hydrogen for fuel cell-powered cargo handling equipment (CHE). By conducting this demonstration, valuable insights into the technical requirements of mobile hydrogen fueling and the economic viability of this approach within a port complex can be gained.

Electric Charging Infrastructure

The challenges of installing charging infrastructure include costs, permitting, UL certification of equipment, utility interconnection requirements and extended timeline and requirements for grid upgrades, all of which need to be better understood and streamlined. In addition, CPUC modeling and forecasting need to be updated to reflect increased regulatory requirements from ACT, ACF, and ISR regulations which are requiring fleets to begin transitioning to BETs. Under existing CPUC regulations, investor owned utilities can only build just in time grid upgrades and need to have the ability to upgrade the grid in advance of these deployments in high priority corridors such as the I-710 where there is significant truck traffic between the San Pedro Bay Ports and the warehouse facilities in the Inland Empire.

Continued technology advancements in LD infrastructure have facilitated development of corresponding codes and standards for MD and HD infrastructure including adoption of a Megawatt Charging Standard (MCS) standard for high power megawatt charging. Additionally, SCE's Charge Ready Transport Program and Los Angeles Department of Water and Power's (LADWP) Commercial EV Charging Station Rebate Program includes funding for charging infrastructure.

LD EV charging infrastructure is commercially available, and the market is aligning towards the North American Combined Charging Standard (CCS1) while MD and HD charging infrastructure using CCS1 connectors are commercially available in an early deployment stage. The CCS1 connector continues to be the standard connector for MD and HD charging up to 350 kW direct current (DC) in the United States. Charging Interface Initiative (CharIN) released a Megawatt Charging System (MCS) connector in June 2022 for Class 6 -8 Evs designed for a maximum current of 3,000 A at up to 1,250V for charging up to 3.75 MW DC which has not yet been adopted. Currently there are no MD or HD Evs capable of accepting charging above 350 kW DC. There is also an agreed upon SAE J3068 connector standard for single-phase and three-phase AC charging as well as Tesla's semi charging connector. Challenges and costs of installing MD and HD charging infrastructure increases exponentially compared to LD infrastructure due to higher power requirements.

South Coast AQMD is seeking both state and federal funding to lead local and regional collaboratives to create MD/HD charging infrastructure networks. SCAG is developing a six county regional MD/HD charging and hydrogen fueling infrastructure plan as part of the CEC eTRUC project to develop and demonstrate high power DC fast charging for HD BETs. A detailed plan for the San Pedro Bay Ports and the I-710 corridor will be created using advanced modeling and additional data sources. In a related effort, Metro has committed $50 million of its funding to deploy charging for HD BETs between the San Pedro Bay Ports and along the I-710 corridor. South Coast AQMD also partnered with private entities to build and expand the MD/HD charging network and submitted proposals to DOT to support the BETs and equipment at the Ports and facilitate electrifying long-haul transportation. There are also additional state and federal funding opportunities under CARB, CEC, and U.S. EPA for HD electrification and climate pollution reduction.

New, ongoing, and recently completed electric charging infrastructure projects include: 1) JETSI Pilot Project with installation of 350 kW DC fast chargers to support 100 Daimler and Volvo Class 8 BETs at NFI and Schneider; and 2) Switch-On Project with installation of multiple DC fast chargers to support 70 Volvo Class 8 battery electric drayage/freight trucks at eight fleets.

The Draft 2024 Plan Update identifies key opportunities while clearly leading the way for demonstration and deployment of hydrogen fueling and charging infrastructure. Future projects may include the following:

- continued development and demonstration of distributed hydrogen production and fueling stations from multiple providers, including energy stations with electricity and renewable hydrogen co-production and higher pressure (10,000 psi) hydrogen dispensing and scalable/higher throughput;
- development of additional sources of hydrogen production and local generation of hydrogen for fueling stations far from local production sources to better meet demand of FCVs;
- development of carbon-natural (or low carbon intensity) hydrogen production, distribution, and infrastructure network through a partnership with regional hydrogen hub projects;
- large scale deployments of commercial large fleet and public charging infrastructure to meet needs for owner operators/small fleets/large fleets for various segments (drayage, last mile delivery, short regional haul, and corridor charging for long-haul applications);
- development of fleet tools to assist in successful operation for drayage, last mile delivery, short regional haul and long-haul applications;

- development of low and zero emission alternative charging solution (ACS) technologies to accommodate delays in deploying permanent EV charging infrastructure due to lead times for grid upgrades or provide temporary power and/or backup power generation;
- development and demonstration of micro-grid systems to support load-shifting, energy resilience, and lower operating energy costs;
- demonstration and installation of infrastructure to support battery electric and fuel cell electric LD, MD and HD fleets, and ways to reduce cost and incentivize incremental costs over conventionally fueled vehicles, meet fleet operational needs, improve reliability, and integrate with battery energy storage, renewable energy and energy management strategies (e.g., vehicle-to-grid or vehicle-to-building functionality, demand response, load management);
- creation of MD/HD charging and hydrogen fueling regional infrastructure planning efforts; and
- deployment of infrastructure corresponding to codes and standards specific to LD, MD and HD vehicles, including standardized connectors, fuel quality, communication protocols, and open standards and demand response protocols for EV chargers to communicate across charging networks, fleet telematics, and vehicle platforms.

Hydrogen / Mobile Fuel Cell Technologies

South Coast AQMD supports hydrogen fuel cell technologies as one option in the technology portfolio; the agency is dedicated to assisting federal and state government programs to deploy LD, MD, and HD fuel cell electric vehicles (FCEVs).

Calendar Years 2015-2019 were a critical timeframe for the introduction of LD hydrogen FCEVs. In 2014, Hyundai introduced the Tucson FCEV for lease. In 2015, Toyota commercialized the Mirai, the first FCEV available to consumers for purchase. In December 2016, Honda started commercial lease of its 2017 Clarity FCEV. The 2019 Hyundai Nexo was the second FCEV offered for sale and lease in California. In the past, Clean Fuels funding has gone towards leases for LD FCEVs as part of its technology outreach efforts for conferences and events in overburdened communities.

Fuel cells can play a role in MD and HD applications where battery recharge time and vehicle range, although improving, is insufficient to meet fleet operational requirements. The Hydrogen Fuel Cell Partnership's (H2FCP, previously known as California Fuel Cell Partnership or CaFCP) 2030 Vision[15] released in July 2018 provides a broader framework for the earlier MD and HD Fuel Cell Electric Truck Action Plan completed in October 2016, which focused on Class 4 parcel delivery trucks and Class 8 drayage trucks with infrastructure development and established metrics for measuring progress. The CaFCP's HD Vision released in July 2021 sets an interim milestone of 70,000 Class 8 fuel cell electric trucks supported by 200 HD hydrogen stations operating in California and beyond by 2035.

South Coast AQMD has created many alliances with large OEMs and will continue to fund projects with these OEMs over the next year to develop HD fuel cell trucks. One player in the HD fuel cell truck space is Cummins who acquired Hydrogenics and Efficient Drivetrains, Inc. (EDI) to develop fuel cell powertrains. Cummins is currently working on the ZECT 2 and a CEC/South Coast AQMD project to develop and demonstrate fuel cell drayage trucks with next generation fuel cell module – easy to package

[15] CaFCP's The California Fuel Cell Revolution, A Vision For Advancing Economic, Social, and Environmental Priorities (Vision 2030), September 4, 2018.

system design and other innovative integration strategies. In June 2021, South Coast AQMD recognized $500k from U.S. EPA to demonstrate two Hyundai Class 8 fuel cell trucks with a range of up to 500 miles for regional and long-haul operations. In 2022, Volvo and Daimler also announced a joint venture to develop fuel cell powered trucks. In 2023, South Coast AQMD was awarded $5,000,000 from US. EPA Targeted Airshed Program to demonstrate and deploy six Daimler (Freightliner) Class 8 hydrogen fuel cell trucks with the partnership of Cummins that will be leased through Penske to various Southern California fleet operators.

The CaFCP Fuel Cell Electric Bus Road Map released in September 2019 supports implementation of CARB's Innovative Clean Transit and Zero Emission Airport Shuttle regulations. SunLine Transit Agency (SunLine) received a U.S. EPA Targeted Airshed grant in June 2020 to deploy six fuel cell transit buses, in addition to their existing fleet of 26 fuel cell and four battery electric transit buses as well as a recently upgraded 900 kg/day hydrogen station capable of supporting up to 30 fuel cell transit buses. SunLine has accepted and commissioned five of the buses into its fleet. In August 2021, the Clean Fuels Program committed $531,166 to a $2 million project to develop and demonstrate two MD fuel cell transit buses at SunLine. Additional outlets for hydrogen fueling infrastructure for these buses will also be developed.

In March 2021, Frontier Energy was awarded $25,000 to perform a high-flow bus fueling protocol development project as a part of the DOE H2@Scale program with partners including SoCalGas, Shell, and NREL. NREL was also awarded $25,000 for California HD Infrastructure Research, and UC Davis was awarded $50,000 for California Hydrogen Systems Analysis. Projects aim to fill in the gaps between LD and HD hydrogen fueling infrastructure to encourage the expansion of hydrogen fueling infrastructure as more state and federal policies are developed or passed. In addition, as more fuel cell MD/HDVs are commercialized, this research becomes more pivotal to ensuring sufficient hydrogen fueling stations are available.

The Draft 2024 Plan Update identifies key opportunities while clearly leading the way for pre-commercial demonstrations of OEM FCEVs. Future projects may include the following:

- development and demonstration of cross-cutting fuel cell applications (e.g. scalable and cost-effective fuel cell powertrain components);
- development and demonstration of fuel cells in off-road, locomotive and commercial harbor craft applications such as port cargo handling equipment, switcher locomotives and tugs;
- demonstration of FCEVs in controlled fleet applications in the Basin;
- coordination with FCEV OEMs to establish a roadmap to commercialization by overcoming barriers to economically competitive FCEVs and develop realistic scenarios for large scale deployment;
- development and implementation of strategies with government and industry to build increasing scale and renewable content in the hydrogen market including certification and testing of hydrogen as a commercial fuel to create a business case for investments as well as critical assessments of market risks to guide and protect these investments;
- repurposing fuel cells and hydrogen tanks for other secondary energy production and storage uses, as well as reusing fuel cells and hydrogen tanks, and approaches to recycle catalysts and other metals; and
- fuel cell standby power generators.

Electric / Hybrid Technologies

To meet the NAAQS, a primary focus continues to be on zero and near-zero emission technologies. A key strategy to achieve these goals is through wide-scale transportation electrification. South Coast AQMD supports projects to address concerns regarding cost, battery life, all-electric range, and OEM commitment. Integrated transportation systems can encourage further emission reductions by matching Evs to typical consumer and fleet duty cycles and demands including drayage, short regional haul, and last mile delivery. There are Class 8 BETs CARB and U.S. EPA certified, commercially available, and eligible for incentives from Hybrid and Zero Emission Truck and Bus Voucher Incentive Project (HVIP), Carl Moyer, Volkswagen Mitigation Trust, Voucher Incentive Program, and CAPP funding.

Development and deployment of zero emission goods movement and freight handling technologies remains one of the top priorities for the South Coast AQMD to support balanced and sustainable growth at the San Pedro Bay Ports as well as freight/logistics facilities throughout the Basin. South Coast AQMD continues to work with our regional partners, including the San Pedro Bay Ports, Southern California Association of Governments (SCAG) and Los Angeles County Metropolitan Transportation Authority (Metro) to demonstrate and deploy technologies that are technically feasible, cost-effective with the assistance of incentives and/or grant funding, and beneficial to all stakeholders. Specific technologies include zero emission trucks/freight handling equipment (battery and/or fuel cell), or plug-in hybrid powertrains, and linear synchronous motors for trucks. Additionally, the California Sustainable Freight Action Plan outlines a blueprint to transition the state's freight system to an environmentally cleaner, more efficient, and economical system, including a call for a zero and near-zero emission vehicle pilot project in Southern California. The Zero Emission 2028 Roadmap 2.0 for Los Angeles 2028 Olympics corroborates this effort, calling for an additional 25% each in GHG and criteria pollutant reductions. The San Pedro Bay Ports Clean Air Action Plan Update (2017) calls for zero emissions cargo handling equipment by 2030 and zero emission drayage trucks by 2035, respectively.

HD hybrid vehicles have historically been optimized for fuel economy, under the adopted CARB and EPA regulation, new hybrid powertrains must co-optimize for both criteria emissions and fuel economy by either by meeting the criteria standard by engine itself or as a combined system. These hybrid systems could be both plug-in and non-plug-in configurations, by focusing on electrifying key engine subsystems and energy recovery to provide engine assistance during transient operations. Furthermore, CARB's Advanced Clean Trucks (adopted 2020) and Advanced Clean Fleets (adopted 2022) regulations allow sales of plug-in hybrid vehicles capable of zero-emission operation as an alternative compliance pathway for meeting the manufacturer and fleet zero emission vehicle mandate.

New, ongoing, and recently completed zero emission battery electric technology projects include: 1) JETSI Pilot Project with deployment of 100 Daimler and Volvo Class 8 BETs for drayage and regional haul at NFI and Schneider funded by $16 million from CARB, $11 million from CEC, $8 million from MSRC, $5.5 million from the Clean Fuels Fund, $5 million from SCE, and $3 million from the San Pedro Bay Ports; 2) Switch-On Project with deployment of 70 Volvo Class 8 battery electric drayage/freight trucks at eight fleets funded with $20 million from the U.S EPA Targeted Airshed grant; 3) Daimler Customer Experience project to demonstrate eight Class 6 and 8 BETs and fast charging infrastructure funded with $1 million by the Clean Fuels Fund; 4) Daimler Innovation Fleet project to demonstrate five Class 6 and 15 Class 8 BETs with $13 million from the Clean Fuels Fund , $1 million from the U.S. EPA Clean Air Technology Initiative grant, and $2 million from the San Pedro Bay Ports; 5) Daimler Zero Emission Electric Delivery Truck project, a commercial deployment of 35 Daimler Class 6 and Class 8 BETs funded

by $4 million from the U.S. EPA Targeted Airshed grant, and 6) development and demonstration of two Cummins/Meritor battery electric Class 8 refuse trucks with South Coast AQMD Special Revenue Funds.

Opportunities to develop and demonstrate technologies that could enable expedited widespread use of pre-commercial and commercial battery electric and hybrid-electric vehicles in the Basin include the following:

- demonstration of battery electric technologies for cargo handling and container transport operations, e.g., HD battery electric drayage trucks;
- large scale deployments of commercial battery electric vehicles (i.e. 50 or more vehicles) to prove feasibility and develop fleet tools to assist in successful operation for drayage and short regional haul operations;
- demonstration of MD battery electric vehicles in package delivery or last mile operations, e.g., battery electric delivery vans;
- development and demonstration of battery electric off-road equipment; e.g. battery electric off-road construction equipment, yard tractors, forklifts, or top handlers with wireless charging;
- demonstration of niche application battery electric MD and HD vehicles, including school and transit buses, shuttle buses, MD vocational trucks, and refuse trucks with short-distance fixed service routes;
- demonstration of integrated programs that make best use of electric drive vehicles through interconnectivity between fleets of shared electric vehicles and mass transit, and rideshare services that cater to multiple users and residents in disadvantaged communities;
- development of eco-friendly intelligent transportation system (ITS), geofencing, and Eco-Drive strategies to maximize emission reductions and energy consumption when driving in disadvantaged communities; demonstrations that encourage electric drive vehicle deployment in autonomous applications; optimized load-balancing strategies and improved characterization of in-duty drayage cycles and modeling/simulations for cargo freight and market analysis for zero emission HD trucks;
- development of higher density battery technologies for use in HD vehicles;
- repurposing EV batteries for other or second life energy storage uses, as well as reusing battery packs and approaches to recycle lithium, cobalt and other metals; and
- development of a methodology to increase capability to accept fast-charging and resultant life cycle and demonstration of effects of fast-charging on battery life and vehicle performance.

Stationary Clean Fuel Technologies

Although stationary source Nox emissions are small compared to mobile sources in the Basin, there are applications where clean fuel technologies or processes can be applied to reduce NOx, VOC and PM emissions. As discussed in engine systems, the use of low and zero carbon fuels could also be used in stationary applications; it is easier to develop optimized engine systems and stationary sources typically operate in steady-state modes.

Additionally, alternative energy storage could be achieved through vehicle-to-grid or vehicle-to-building technologies, as well as power-to-gas that could allow curtailed renewable electricity to be stored as hydrogen fuel. Microgrid demonstration and deployment projects to support large scale deployment of zero emission vehicles and equipment could also be incorporated into new or existing deployment projects to

facilitate installation of infrastructure. UCR's Sustainable Integrated Grid Initiative and UCI's Advanced Energy and Power Program, funded in part by the South Coast AQMD, for example, could assist in evaluation of these technologies.

Projects conducted under this category may include:

- development and demonstration of reliable, low emission stationary technologies and fuels (e.g., new innovative low Nox burners and fuel cells);
- exploration of renewables, waste gas and produced gas sources for cleaner stationary technologies;
- evaluation, development and demonstration of advanced control technologies for stationary sources;
- vehicle-to-grid, vehicle-to-building, or other stationary energy demonstration projects to develop sustainable, low emission energy storage alternatives and reduce total cost of ownership (TCO); and
- development and demonstration of microgrids with photovoltaic/fuel cell/battery storage/EV chargers and energy management to support large scale deployment of zero emission vehicles and equipment.

The development, demonstration, deployment and commercialization of advanced stationary clean fuel technologies will support control measures in the 2022 AQMP that reduce emissions of NOx and VOCs from traditional combustion sources by replacement or retrofits with zero and near-zero emission technologies. In 2023, UCI was awarded $150,000 to study regional air quality and health impacts of utilizing Hydrogen Blends in commercial buildings and industrial applications as a part of a CEC award that focuses on the decarbonization of California.

Fuel and Emissions Studies

Monitoring of pollutants in the Basin is extremely important, especially when linked to a particular sector of the emissions inventory. This information highlights the need for further emission studies to identify emissions from high polluting sectors resulting from these technologies.

Over the past few years, the South Coast AQMD has funded emission studies to evaluate the impact of tailpipe emissions of biodiesel, renewable diesel, and ethanol fueled vehicles mainly focusing on criteria pollutants and GHG emissions. These studies showed that biofuels, especially biodiesel in some applications and duty cycles, can contribute to higher NOx emissions while reducing other criteria pollutant emissions. South Coast AQMD expects additional fuel and emission studies needed on non-carbon containing fuel such as hydrogen.

In addition, as the market share for gasoline direct injection (GDI) vehicles has rapidly increased from 4 percent of all vehicle sales in the U.S. to an estimated 60 percent between 2009 and 2016, it is important to understand air quality impacts from these vehicles. South Coast AQMD has funded studies to investigate both physical and chemical composition of tailpipe emissions, focusing on PM from GDI vehicles as well as secondary organic aerosol formation formed by the reaction of gaseous and particulate emissions from NG and diesel HD vehicles. The results from these studies suggest the addition of a particulate filter for controlling particulate emissions from GDI vehicles. On April 12, 2023, the U.S. Environmental Protection Agency (EPA) announced new multi-pollutant standard for Light-Duty and medium-duty vehicles starting with model year 2027 which lowered the PM standard further that will require the use of particulate filter.

In 2017, South Coast AQMD initiated a basin wide in-use real-world emissions study, including fuel usage profile characterization and an assessment of the impacts of current technology and alternative fuels. The study was concluded in late 2022 with results suggest real-world emissions vary greatly between applications and fuel types; but alternative fueled technologies such as NG fueled vehicles, especially ones certified to near-zero emission levels, are significantly lower in emissions compared to diesel baseline. The results of the study also contributed to the new EMFAC 2021 emissions model.

In recent years, non-exhaust PM emissions has been gaining attention. Vehicles emit inhalable particles from the exhaust system but also from non-exhaust sources including brake wear, tire and road wear, clutch wear and road dust resuspension. The non-exhaust sources have not been regulated because they are difficult to measure and control. Model predictions suggest that traffic-related emissions of both PM2.5 and PM10 will eventually be dominated by non-exhaust sources. SCAQMD has been engaging in researching effort to control these emissions by having a greater understanding of their physical and compositional characteristics and to support MATE VI efforts.Based on higher average summer temperatures over the past few years, there is interest on how higher temperatures impact ozone formation. A project was launched in 2019 to evaluate meteorological factors and trends contributing to recent poor air quality in the Basin. These types of studies may be beneficial to support the CERPs developed under AB 617, as well as other programs targeting benefits to residents in disadvantaged communities. With the phase in of various CARB regulations such as the Omnibus regulation HD inspection and maintenance (HD I/M) program as well as the upcoming MATES VI study in 2025, there will be a continued need for the Clean Fuels program to focus on additional fuels and emissions studies, some areas of focus include:

- demonstration of remote sensing technologies to target different high emission applications and sources;
- studies to identify health risks associated with ultrafine and ambient particulate matter to characterize toxicity and determine specific combustion sources, and to support MATES VI;
- in-use emission studies using biofuels, including renewable diesel and other alternative fuels;
- in-use emission studies to determine impact of new technologies, in particular new near-zero emission engine technologies and hybrids on local air quality as well as the benefit of telematics on emission reduction strategies;
- on-board sensing and reporting system to identify low exposure truck routes;
- particulate matter emission study for brake- and tire-wear for LD, MD, and HD vehicles and locomotives;
- lifecycle energy and emissions analyses to evaluate conventional and alternative fuels;
- analysis of fleet composition and its associated impacts on criteria pollutants;
- evaluation of emissions impact of low- and zero-carbon fuels/blends on the latest technology engines; and
- evaluation of impact of higher ambient temperatures on emissions of primary and secondary air pollutants.

Renewable Fuel Infrastructure

The Clean Fuels Program has provided funding for significant demonstration and commercialization efforts as well as other local, state and federal agencies: 1) upgrade and buildup of public and private infrastructure

projects, 2) expansion of the network of public access and fleet fueling stations based on the population of existing and anticipated vehicles, 3) infrastructure to accommodate transportation fuels with very low gaseous and GHG emissions, and 4) local production of clean, low carbon intensity, renewable transportation fuels. There are commercial public access NG refueling stations throughout Southern California with a certain percentage of renewable gas in the pipeline. Additionally, incentive funds have been made available for RNG infrastructure. South Coast AQMD has funded several RNG refueling projects through the Carl Moyer Program. The Clean Fuels program expects minimum funding allocated for RNG infrastructure.

Health Impacts Studies

Assessment of potential health risks linked to exposure to pollution is extremely important. Studies indicate that ultrafine particulate matter (PM) can produce irreversible damage to children's lungs, which highlights the need for further studies to identify health impacts resulting from these technologies.

Previous studies of ambient levels of toxic air contaminants, such as the MATES studies, have found that diesel exhaust is the major contributor to cancer risk from air toxics. South Coast AQMD completed MATES V in August 2021 to update the emissions inventory of toxic air contaminants, as well as modeling to characterize risks, including measurements and analysis of ultrafine particle concentrations typically emitted or subsequently formed from vehicle exhaust. Findings from the MATES V report showed that air toxics cancer risk has decreased 40% since MATES IV, with average multi-pathway air toxics cancer risk at 454 in a million. The highest risk locations are at LAX and the Ports along goods movement and transportation corridors. Diesel PM continues to be the major contributor accounting for over 60% of the overall air toxics cancer risk. For the first time, chronic non-cancer risk was estimated with chronic hazard indices of 5 to 9 among the 10 stations in the MATES V study. MATES VI is in the planning stages with monitoring scheduled to start in mid 2025.

Furthermore, despite recent advancements in toxicological research related to air pollution, the relationship between particle chemical composition and health effects is still not completely understood, especially for biofuels, NG and other alternative fuels. In 2015, South Coast AQMD funded chamber studies as part of the 200 Vehicle Study to further investigate the toxicological potential of emissions from MD and HD vehicles, such as ultrafine particles and vapor phase substances, and to determine whether substances such as volatile or semi-volatile organic compounds are being emitted in lower mass emissions that could pose harmful health effects. The results indicated higher SOA emissions from CNG vehicles compare to baseline, due to excess lube oil consumption, ammonia emissions and lack of particulate filters.

Technology Assessment and Transfer/Outreach

Since the Clean Fuels Program depends on the deployment and adoption of demonstrated technologies, technology transfer and outreach efforts are essential to its success. This core area encompasses assessment of advanced technologies, including retaining outside technical assistance to expedite implementation of low emission and clean fuel technologies, coordinating activities with other organizations and educating end users of these technologies. Technology transfer efforts include supporting various incentive programs that encourage the purchase of cleaner technologies, cosponsoring technology-related conferences, workshops, and other events, and disseminating information on advanced technologies to various audiences (i.e., residents in AB 617 or disadvantaged communities, local governments, funding agencies, technical

audiences). South Coast AQMD's AB 617[16] program is designed to reduce emissions in communities disproportionately impacted by air pollution. TAO conducted additional outreach to AB 617 communities regarding available zero and near-zero emission technologies and incentives to accelerate the adoption of cleaner technologies. Incentivizing deployment of zero emission HD trucks has been included in the CERPs and an RFP for zero emission HD truck incentive funding was released in September 2023 for four out of the six AB 617 communities.

Engine Systems/Technologies

To achieve the emission reductions required for the Basin, ICEs used in the HD sector will require widespread implementation of zero emission technologies as outlined in CARB's 2022 Mobile Source Strategy and 2022 AQMP. However, the path to 100 percent zero emission trucking sector will take time Meanwhile, with the recent CARB announcement, ICE engines will slowly transitioning to ultra-low NOx level starting MY 2027.

The effort with low emission ICE engines started back in 2016, with CWI achieved a new ultra-low NOx threshold by commercializing the first on-road HD engine to be certified to CARB's optional low NOx standard of 0.02g NOx/bhp-hr. The 8.9 liter (8.9L) ISL-G NG engine demonstrated that an ICE could achieve NOx exhaust emission levels 90 percent cleaner than the existing federal standard. Powering these vehicles with low Carbon Intensity renewable fuels or biomethane to help address GHG objectives became a popular alternative for the HD transportation sector. The 8.9L engine works well in refuse and other vocational trucks as well as transit and school buses. Later, Cummins also certified the different displacement version of the engine for more market sectors including a more powerful 15L NG engine available starting MY 2024.

Although no 0.02g NOx diesel technology is commercially available today, development and demonstration efforts have proven low NOx diesel technology is viable. South Coast AQMD has been working closely with CARB, U.S. EPA and others on defining low NOx diesel technology pathways via several projects. We do expect next generation lower NOx diesel engines to be commercially available in the MY 2027 timeframe, in time for the phase in of the EPA and CARB regulations.

More recently, Cummins announced a hydrogen powered ICE with near-zero NOx capabilities ready for implementation in the 2027 timeframe. While using hydrogen in fuel cells is a core strategy to achieve the air quality goals in this region, in the near term, it is possible to use hydrogen in ICE for on- and off-road vehicles as a bridge technology to fuel cells. Hydrogen ICE has the benefit of using existing engine platforms, insensitivity to hydrogen quality, and use of existing hydrogen production and distribution systems that can deploy hydrogen refueling infrastructure which could later complement fuel cell vehicles. Recognizing the importance of hydrogen fuel, there is a need for research and development that can achieve significant efficiency and emissions improvements in hydrogen combustion engines. As a result, the Draft 2024 Plan Update includes on-road truck demonstrations and real-world emissions benefit analysis using hydrogen as a fuel for internal combustion.

The Draft 2024 Plan Update continues to Incorporate pursuit of cleaner engines and hybrid powertrains for the HD sector but is starting to transition to zero emission technologies. Future engine projects will continue to support the development, demonstration and emissions verification/certification of engines and powertrains that can achieve needed near-term emission reductions. At the same time, aggressive GHG

[16] http://www.aqmd.gov/nav/about/initiatives/environmental-justice/ab617-134

emission reduction targets set forth by both CARB and U.S. EPA have invigorated interest in revisiting low- and zero carbon alternative fuels for those high power/torque applications such as hydrogen ICE. While the GHG benefit is relatively easy to assess by fuel source, it is also important to understand the criteria emissions impact under real-world conditions and over its useful lifetime to ensure reduction of criteria pollutants and GHGs are fully realized.

The Draft 2024 Plan Update includes potential projects that the South Coast AQMD might participate with federal, state, and other private entities towards these efforts. Specifically, these projects are expected to target the following:

- demonstration of ultra-low emissions and improved higher efficiency gaseous and liquid fuel powered engines for HD vehicles and high horsepower application projects;
- demonstration of gaseous and liquid fuel powered engines to support hybrid and plug-in hybrid vehicle technology;
- demonstration of alternative fuel engines for on- and off-road applications;
- vehicle level demonstration of engine systems that employ advanced engine design features, cylinder deactivation, improved exhaust or recirculation systems, and aftertreatment devices; and
- further development of robust aftertreatment systems which can maintain certified emissions levels under a wide variety of duty cycles and throughout the vehicle's useful life.

U.S. EPA's recent adoption of a national low NOx standard for on-highway HD engines starting in 2027 will further motivate manufacturers to develop lower-NOx emitting technologies expected to result in greater NOx emission reductions. Low- and zero carbon alternative fuels for new low emitting engines will continue to emerge as timelines for GHG reductions approach.

Emission Control Technologies

Over the last several decades, diesel emissions have been greatly reduced with introduction of RNG, hydrogen, biofuels, synthetic and low carbon fuels into the engine but also via aftertreatment controls such as close coupled catalysts, advanced SCR and DPF catalysts coupled with electrically heated diesel exhaust fluid (DEF) dosers as well as advanced control strategies using cylinder deactivation, which have proven to lower emissions to near-zero and increase efficiency. Recently, particulate matter (PM and PN) emissions from GDI fueled LD vehicles, gaseous and gasoline fueled MD and HD vehicles have gathered attention due to the lack of particulate filters. While relative PM levels are low and below the applicable standard, concerns on ultra-fine emissions needs to be assessed. South Coast AQMD will continue to fund studies to help mitigate emissions concerns for gasoline and NG fueled engines. Onboard emissions sensors have been identified by CARB and other agencies as a reliable method for assessing in-use emissions compliance. At the same time, researchers have proposed to use sensors, coupled with GPS, cellular connection, weather, traffic, and other online air quality models together to enable advanced concepts like Geofencing, Eco-routing, and more. Similar strategies have been presented in CARB's latest 2022 SIP Strategy. The most promising of these technologies will be considered for funding, specifically:

- demonstration of particulate filter technology for LD, MD and HD gasoline and gaseous fueled vehicles;
- develop, evaluate, and demonstrate onboard sensor-based emissions monitoring methodology; and

- develop, evaluate, and demonstrate cloud-based emissions and energy management system.

Target Allocations to Core Technology Areas

Figure 17 presents the potential allocation of available Clean Fuels Program funding, based on South Coast AQMD projected program costs of $33 million for all potential projects. The actual project expenditures for 2024 will be less than the total South Coast AQMD projected program costs since not all projects will materialize. Target allocations are based on balancing technology priorities, technical challenges and opportunities discussed previously, and near term versus long term benefits with the constraints on available South Coast AQMD funding. Although the Clean Fuels Program must consider cost effectiveness of emission reductions as one of several factors in determining which technologies to fund the Legislature allows for flexibility in prioritizing technologies with a higher cost effectiveness if it is deemed necessary for South Coast AQMD to meet its NAAQS. The 2022 AQMP specifically calls for accelerated deployment of zero emission technologies wherever feasible to achieve the 2015 8-hour ozone standard and the associated CARB 2020 Mobile Source Strategy shows the need for rapid implementation of zero-emission transportation. Specific contract awards throughout 2024 will be based on this proposed allocation, quality of proposals received, and evaluation of projects against standardized criteria and ultimately South Coast AQMD Board approval. Some of the Clean Fuels Program projects may utilize the MSRC discretionary fund depending on the project types and the MSRC's annual Work Program.

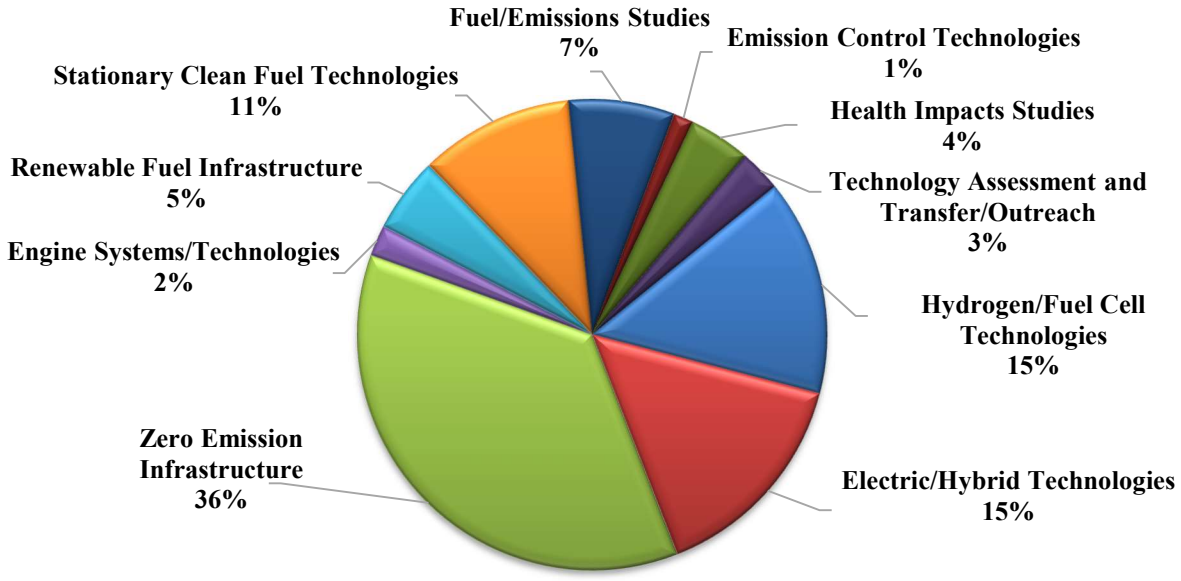

Figure 17: Projected Cost Distribution for Potential South Coast AQMD Projects in 2024 ($33M)

CLEAN FUELS PROGRAM

Program Plan Update for 2024

This section presents the Clean Fuels Program Plan Update for 2024. The proposed projects are organized by program areas and described in further detail, consistent with the South Coast AQMD budget, priorities and the best available information on the state-of-the-technology. Although not required, this Plan also includes proposed projects that may also be funded by revenue sources other than the Clean Fuels Program, through state and federal grants for clean fuel technologies, incentive programs such as AB 617 Community Air Protection Program (CAPP) funding, Volkswagen Mitigation and Carl Moyer, and VOC and NOx mitigation.

Table 9 summarizes potential projects for 2024 as well as the distribution of South Coast AQMD costs in some areas as compared to 2023. The funding allocation continues the focus on development and demonstration of zero and near-zero emission technologies including infrastructure to support vehicles and off-road equipment. For the 2024 Draft Plan Update, there is a continuing focus on zero emission technologies including funding for hydrogen/fuel cell technologies, electric/hybrid technologies, and zero emission infrastructure. Zero emission infrastructure was formerly included within hydrogen/fuel cell and electric/hybrid technologies, but given its increasing importance it is now being presented as a separate category. There are significant decreases in funding for RNG infrastructure and engine systems/ technologies as near-zero engine development has been significantly reduced as funding is increasingly shifted to zero emission technologies and infrastructure for future planned projects in 2024, including:

- HD zero emission battery electric and fuel cell trucks;
- HD zero emission infrastructure development, demonstration, deployment and planning, including ACS solutions;
- Onboard sensor development for emissions monitoring and improved efficiency;
- Microgrid demonstrations to support zero emission infrastructure;
- Battery and fuel cell electric transit and school bus fleet charging/fueling infrastructure;
- HD diesel truck replacements with zero emission trucks; and
- Fuel and emissions studies, such as airborne measurements and analysis of NOx emissions and assessing emission impacts of hydrogen- fueled ICE, and testing for particulate matter emissions from brake- and tire-wear.

As in prior years, funding allocations again align well with the South Coast AQMD's FY 2023-24 Goals and Priority Objectives, which includes supporting development of cleaner advanced technologies. Overall, the Clean Fuels Program is designed to ensure a broad portfolio of technologies, complement state and federal efforts, and maximize opportunities to leverage technologies in a synergistic manner.

Each of the proposed projects described in this Plan, once fully developed, will be presented to the South Coast AQMD Governing Board for approval prior to contract initiation. This Plan Update reflects the maturity of the proposed technology and identifies contractors to implement projects, participating host sites and fleets, and securing sufficient cost-sharing to complete projects, and other necessary factors. Recommendations to the South Coast AQMD Governing Board will include descriptions of technologies

to be demonstrated or deployed, their applications, proposed scope of work, and capabilities of selected contractor(s) and project teams, in addition to the expected costs and project benefits as required by H&SC 40448.5.1.(a)(1). Based on communications with all organizations specified in H&SC 40448.5.1.(a)(2) and review of their programs, projects proposed in this Plan do not appear to duplicate any past or present projects.

Funding Summary of Potential Projects

The remainder of this section contains the following information for each of the potential projects summarized in Table 9.

Proposed Project: Descriptive title and a designation for future reference.

Expected South Coast AQMD Cost: Estimated proposed South Coast AQMD cost-share as required by H&SC 40448.5.1.(a)(1).

Expected Total Cost: Estimated total project cost including South Coast AQMD cost-share and cost-share of outside organizations expected to be required to complete the proposed project. This is an indication of how much South Coast AQMD public funds are leveraged through its cooperative efforts.

Description of Technology and Application: Brief summary of proposed technology to be developed and demonstrated, including expected vehicles, equipment, fuels, or processes that could benefit.

Potential Air Quality Benefits: Brief discussion of expected benefits of proposed project, including expected contribution towards meeting the goals of the 2022 AQMP, as required by H&SC 40448.5.1.(a)(1). In general, the most important benefits of any technology research, development and demonstration program are not necessarily realized in the near-term. Demonstration projects are generally intended to be proof-of-concept for an advanced technology in a real-world application. While emission benefits, for example, will be achieved from the demonstration, true benefits will be seen over a longer term, as a successfully demonstrated technology is eventually commercialized and implemented on a wide scale.

Table 9: Summary of Potential Projects for 2024

Proposed Project	Expected SCAQMD Cost $	Expected Total Cost $
Zero Emission Infrastructure		
Develop and Demonstrate Hydrogen Production and Fueling Stations	2,000,000	6,500,000
Develop and Demonstrate Permanent Electric Charging Infrastructure	7,000,000	232,000,000
Develop and Demonstrate Innovative Charging Solutions for Grid Support	3,000,000	7,000,000
Subtotal	$12,000,000	$245,500,000
Hydrogen/Mobile Fuel Cell Technologies		
Develop and Demonstrate Hydrogen Research to Support Innovative Technology Solutions for Fueling Fuel Cell Vehicles	100,000	900,000
Develop and Demonstrate MD and HD Fuel Cell Vehicles	4,800,000	20,000,000
Subtotal	$4,900,000	$20,900,000
Electric/Hybrid Technologies		
Develop and Demonstrate MD and HD On-Road Battery Electric Vehicles and Equipment	4,800,000	255,500,000
Demonstrate Light-Duty Battery Electric Vehicles and Plug-In Hybrid Vehicles	160,000	160,000
Subtotal	$4,960,000	$255,660,000
Stationary Clean Fuel Technologies		
Develop and Demonstrate Microgrids with Photovoltaic/Fuel Cell/Battery Storage Energy Management	1,000,000	4,000,000
Develop and Demonstrate Zero or Near-Zero Emission Energy Generation Alternatives	2,500,000	7,000,000
Subtotal	$3,500,000	$11,000,000
Fuel and Emissions Studies		
Conduct In-Use Emission Studies including MATES VI for Advanced Technology Vehicle Demonstrations	1,000,000	4,000,000
Conduct Emission Studies including MATES VI on Biofuels, Alternative Fuels and Other Related Environmental Impacts	1,000,000	4,000,000
Identify and Demonstrate In-Use Fleet Emission Reduction Technologies and Opportunities	400,000	1,500,000
Subtotal	$2,400,000	$9,500,000
Renewable Fuel Infrastructure		
Demonstrate Low-Emission Engine/Generation Technology	1,000,000	2,000,000
Develop, Maintain and Expand Renewable Fuel Infrastructure	300,000	1,000,000
Demonstrate Renewable Transportation Fuel Production and Distribution Technologies	400,000	1,500,000
Subtotal	$1,700,000	$4,500,000

Table 9: Summary of Potential Projects for 2024 (cont'd)

Proposed Project	Expected SCAQMD Cost $	Expected Total Cost $
Health Impacts Studies		
Source Specific Particulate Matter Impacts for MATES VI	1,000,000	1,250,000
Conduct Monitoring to Assess Environmental Impacts including MATES VI	200,000	800,000
Assess Sources and Health Impacts of Particulate Matter including MATES VI	200,000	800,000
Subtotal	$1,400,000	$2,850,000
Technology Assessment and Transfer/Outreach		
Assess and Support Advanced Technologies and Disseminate Information	600,000	1,000,000
Support Implementation of Clean Fuels Incentives and Demonstration Projects	350,000	400,000
Subtotal	$950,000	$1,400,000
Engine Systems/Technologies		
Develop and Demonstrate Advanced Gaseous- and Liquid-Fueled MD and HD Engines and Vehicle Technologies to Achieve Ultra-Low Emissions	500,000	2,000,000
Develop and Demonstrate Low Emission Locomotive Technologies and After Treatment Systems	200,000	1,500,000
Subtotal	$700,000	$3,500,000
Emission Control Technologies		
Develop Methodology and Evaluate and Demonstrate Onboard Sensors for On-Road/Off-Road Vehicles	250,000	1,000,000
Demonstrate On-Road Technologies in Off-Road and Retrofit Applications	200,000	1,000,000
Subtotal	$450,000	$2,000,000
TOTALS FOR POTENTIAL PROJECTS	$32,960,000	$556,810,000

Technical Summaries of Potential Projects

Zero Emission Infrastructure

Proposed Project: Develop and Demonstrate Hydrogen Production and Fueling Stations

Expected South Coast AQMD Cost: $2,000,000

Expected Total Cost: $6,500,000

Description of Technology and Application:

Alternative fuels, such as hydrogen and the use of advanced technologies, such as FCEVs, are necessary to meet future clean air standards. A key element in the widespread acceptance and resulting increased use of alternative fuel vehicles is the development of a reliable and robust infrastructure to support the fueling of vehicles, cost-effective production and distribution and clean utilization of these new fuels.

A challenge to the entry and acceptance of direct-hydrogen FCVs is the limited number and scale of hydrogen fueling and production sites. This project would support the development and demonstration of hydrogen fueling technologies with a focus on MD/HD fueling infrastructure. Proposed projects would address:

Fleet and Commercial Fueling Stations: Further expansion of the hydrogen fueling network based on retail models, providing renewable generation, adoption of standardized measurements for hydrogen fueling, other strategic fueling locations, dispensing pressures that support zero emission vehicle deployment and compatibility with existing CNG stations may be considered.

Energy Stations: Multiple-use energy stations that can produce hydrogen for FCVs or stationary power generation are considered an enabling technology and potentially cost-competitive with large-scale reforming. System efficiency, emissions, hydrogen throughput, hydrogen purity and system economics will be monitored to optimize strategies for hydrogen fueling infrastructure deployment and to produce power and hydrogen from renewable feedstocks (e.g., biomass, digester gas) and store hydrogen in larger scale.

Innovative Fueling Appliances: Home or small scale fueling/charging or portable refueling solutions is an attractive advancement for alternative clean fuels for potential applications. This project would evaluate an innovative hydrogen refueler for cost, compactness, performance, durability, emission characteristics, ease of assembly and disassembly, maintenance and operations. Other issues such as setbacks, building permits, building code compliance and UL ratings for safety would also be evaluated.

CARB projections for on-road FCEVs counts are now 30,800 in 2024 and 61,000 in 2027 in California[17] and the majority of these do not include MD and HD vehicles deployed in the Basin. To meet demand, the number of hydrogen fueling infrastructures needs to be significantly increased and become more reliable in terms of uptime and supply. South Coast AQMD will seek additional funding from CEC and CARB to construct and operate hydrogen fueling stations and take advantage of funding opportunities that may arise soon with the California hydrogen hub application and others such as anticipated adoption of the Advanced Clean Fleets Regulation.

[17] California Air Resources Board. *2021 Annual Evaluation of Fuel Cell Vehicle Deployment & Hydrogen Fuel Station Network Development* (AB 8 Report). September 2021.

Potential Air Quality Benefits:

The 2022 AQMP identifies the use of alternative clean fuels in mobile sources as a key attainment strategy. Pursuant to AQMP goals, the South Coast AQMD has several fleet rules in effect that require public and certain private fleets to purchase clean-burning alternative-fueled vehicles when adding or replacing vehicles to their vehicle fleets. The Warehouse Indirect Source Rule (ISR) also requires certain warehouse owners and operators to comply with the rule by operating clean fuel vehicle technologies. FCEVs constitute some of the cleanest alternative-fuel vehicles today. Since hydrogen is a key fuel for FCEVs, this project would address some of the barriers faced by hydrogen as a fuel with the focus on MD/HD infrastructure and thus assist in accelerating its acceptance and ultimate commercialization. In addition to supporting the immediate deployment of the demonstration fleet, expanding the hydrogen fuel infrastructure should contribute to the market acceptance of fuel cell technologies in the long run, leading to substantial reductions in Nox, VOC, CO, PM and toxic compound emissions from vehicles.

Proposed Project: Develop and Demonstrate Permanent Electric Charging Infrastructure

Expected South Coast AQMD Cost: $7,000,000

Expected Total Cost: $232,000,000

Description of Technology and Application:

There is a critical need to address gaps in EV charging infrastructure availability. Forty-one percent of the 3,916,106[18] EVs sold in the U.S. since 2010 were in California, and of those sales in California, almost half (44 percent) of CVRP[19] rebates issued as of July 2023 were for vehicles in the South Coast AQMD. In addition, the California ZEV Action Plan, which was updated in 2018, calls for 5 million ZEVs and supporting infrastructure by 2030.

There are separate challenges associated with infrastructure for LD EVs vs. MD and HD EVs, which are on opposite ends of the commercialization spectrum. LD EVs and charging infrastructure have long been commercially available with an SAE J1772 connector standard for Level 1 and Level 2 charging. In recent months, multiple LD OEMs and EVSE providers have adopted the CCS1 connector moving towards more reliable, harmonized LD charging network Availability of public fast charging and workplace charging continues to increase and is needed particularly for residents in multi-unit dwellings without easy access to home charging. Availability and costs to deploy infrastructure remain the main challenges for LD EVs.

MD and HD EVs are becoming more commercially available, with multiple OEMs obtaining CARB certification for Class 4 though Class 8 battery and fuel cell electric vehicles. Standards for charging infrastructure to support MD and HD EVs has generally been with the CCS1 connector in North America. Although Tesla have adopted a different connector for their semi-trucks, the CCS1 connector continues to be the standard connector for charging up to 350 kW DC. A separate Megawatt Charging System (MCS) connector is under development by the Charging Interface Initiative (CharIN) for Class 6 -8 EVs for charging up to 4.5 MW DC. There is also an agreed upon SAE J3068 connector standard for single-phase and three-phase AC charging. The challenges and costs of installing MD and HD charging infrastructure have exponentially increased compared to LD infrastructure. Each year there are commercially available options emerging for MD and HD on-road EVs and off-road equipment, charging infrastructure to HD EVs, equipment, and infrastructure. As the deployment of MD and HD EVs and off-road equipment has increased, there is an increasing reliance on the use of standardized charging connectors that are UL or Nationally Recognized Testing Laboratory (NRTL) certified charging infrastructure, as opposed to proprietary charging infrastructure and connectors which can only be used with EVs and equipment manufactured by that OEM or equipment manufacturer. Further, for off-road mobile applications where a fixed charging solution is not feasible, innovative solutions must be explored and demonstrated. There is significant funding provided by the Bipartisan Infrastructure Law and the Inflation Reduction Act that can support overcoming the challenges we expect wide-spready EVSE project to be funded within the next decade. Other federal, state and local funding opportunities have been recently announced or are expected to fund MD/HD public charging infrastructure. South Coast AQMD has partnered with private entities to submit proposals to DOT to support battery electric vehicles and equipment at the Ports and facilitate electrifying long-haul transportation.

This project category is one of South Coast AQMD's continued efforts to:

[18] https://www.veloz.org/ev-market-report/. Q2 2023 data uploaded on 8/2/23.

[19] https://cleanvehiclerebate.org/eng/rebate-statistics

- deploy a network of DC fast charging infrastructure (350kW or more) and rapidly expand the existing network of public EV charging stations including energy storage systems;
- deploy DC fast charging infrastructure (500 kW or more) in conjunction with energy storage and/or solar to support large scale deployments of 50 or more battery electric trucks (BETs) at a single fleet location;
- charging infrastructure and innovative systems (i.e. solar or battery swap) to support MD and HD vehicle and off-road equipment demonstration and deployment projects;
- regional planning for MD/HD charging;
- develop MD/HD charging infrastructure solutions that provide easier installation through reduced grid reliance and increased resiliency;
- develop ACS solutions that provide temporary solutions charging and or mobile backup power;
- support investigation of fast charging impacts on battery life;
- develop intelligent transportation system strategies for cargo containers; and
- develop freight load-balancing strategies as well as to conduct market analysis for zero emission HD trucks in goods movement.

Potential Air Quality Benefits:

The 2022 AQMP identifies zero emission vehicles as a key attainment strategy. MD/HD infrastructure is currently a limiting factor to deploying BETs for many fleets. This proposed project category will reduce PM pollution along major roadways through the expansion of the public EV charging infrastructure network by allowing drivers to shift away from conventional-fueled vehicles to battery and fuel cell EVs. In addition, this project will assist in achieving improved fuel economy and lower tailpipe emissions, further helping the region to achieve NAAQS and protect public health. Expected benefits include the establishment of criteria for emission evaluations, performance requirements and customer acceptability of the technology. This will help both regulatory agencies and OEMs to expedite introduction of ZEVs in the Basin, which is a high priority of the 2022 AQMP.

Proposed Project: Develop and Demonstrate Innovative Charging Solutions for Grid Support

Expected South Coast AQMD Cost: $3,000,000

Expected Total Cost: $7,000,000

Description of Technology and Application:

The South Coast AQMD has been involved in the development and demonstration of battery electric vehicles and has transitions to pre-commercial deployment phase. Over the past few years, serval OEMs have commercialized battery electric medium and heavy-duty (HD) models. As the number of battery electric vehicles increase, the site peak demand increases and often faces long delays in getting sufficient grid capacity. Development and demonstration of innovative charging solutions for providing prime power while the grid capacity is added and backup power is now in high demand. Traditional off-grid power generation using ICE generators are often not preferred and does not fit within the funding guidelines. Innovative charging solutions that combine with the advantages of renewable fuel sources could yield major benefits, including low and zero emissions.

This project category is to apply advanced and innovative power generation technologies to identify best fit low and zero emission electric generation solution for battery electric vehicle charging, and to demonstrate their viability, reliability, and durability, gauge market preparedness, evaluate costs relative to traditional grid power and ICE-based generators. The use of alternative charging solutions and generation (i.e. solar) could support a large scale deployment of battery electric trucks (BETs) and charging infrastructure at a single fleet location where energy storage is optimized for grid reliability and to offset electricity demand charges.

South Coast AQMD is actively pursuing development alternative charging solutions (ACS) to support temporary power charging as well as providing power during grid outage events. These innovative charging solutions ranging from mobile batteries packs, hydrogen fuel cell generators, combustion of renewable fuels, as well as temporary installation of charger via existing electrical systems, Different than permanent infrastructure, which requires long term planning as well as permitting of the site and equipment, ACS systems are mobile and can often deployed quickly and falls under backup generator category for permitting, or local building department for electrical permitting. ACS technologies can also provide power for off-road equipment which also requires mobile charging. Today, ACS systems are relatively new but rapidly becoming commercially available for smaller capacity solutions. Larger systems which often require onboard generation are currently being developed and demonstrated.

Potential Air Quality Benefits:

Certification of battery electric and hybrid electric vehicles and engines and their integration into the Basin's transportation sector is a high priority under the 2022 AQMP. This project is expected to further efforts to develop innovation charging technologies that could be aid in deployment of MD and HD trucks, buses, off-road equipment, and other applications. Benefits will include proof of concept for new technologies, diversification of transportation fuels and lower emissions of criteria, toxic pollutants and greenhouse gases.

Hydrogen / Mobile Fuel Cell Technologies

Proposed Project: Develop and Demonstrate Hydrogen Research to Support Innovative Technology Solutions for Fueling Fuel Cell Vehicles

Expected South Coast AQMD Cost: $100,000

Expected Total Cost: $900,000

Description of Technology and Application:

California regulations require automakers to place increasing numbers of ZEVs into service every year. By 2050, CARB projects that 87% of LD vehicles on the road will be zero emission battery and FCVs.

Many stakeholders are working on hydrogen and fuel cell products, markets, requirements, mandates and policies. California has been leading the way for hydrogen infrastructure and FCV deployment. This leadership has advanced a hydrogen network that is not duplicated anywhere in the U.S. and is unique in the world for its focus on providing a retail fueling experience. In addition, the advancements have identified many lessons learned for hydrogen infrastructure development, deployment and operation. Other interested states and countries are using California's experience as a model case, making success in California paramount to enabling market acceleration and uptake in the U.S. U.S. leadership for hydrogen technologies is rooted in California, a location for implementing many DOE H2@Scale pathways, such as reducing curtailment and stranded resources, reducing petroleum use and emissions, and developing and creating jobs. The technical research capability of the national laboratories can be used to assist California in decisions and evaluations, as well as to verify solutions to problems impacting the industry. Because these challenges cannot be addressed by one agency or one laboratory, in 2018, a hydrogen research consortium was organized to combine and collaborate. Moreover, in 2022 California announced its intention to develop a renewable hydrogen hub as a part of the DOE announcement for an $8B funding opportunity to establish up to ten regional hydrogen hubs to build self-sustaining hydrogen economies of producers and infrastructure in the nation. The Governor's Office of Business and Economic Development (GO-Biz) established Alliance for Renewable Clean Hydrogen Energy Systems (ARCHES) to unite critical public and private stakeholders to build the framework for a California renewable, clean hydrogen hub as such additional hydrogen research studies and projects are foreseen in 2023.

The California Hydrogen Infrastructure Research Consortium focuses on top research needs and priorities to address near-term problems to support California's continued leadership in innovative hydrogen technology solutions needed for fueling FCEVs. These tasks also provide significant contributions to the DOE H2@Scale Initiative. For instance, advances in fueling methods and components can support the development of supply chains and deployments. Tasks completed include data collection from operational stations, component failure fix verification (i.e., nozzle freeze lock), reporting about new fueling methods for MD and HD applications and HD tasks to develop HD reference station design, model HD station capacity with high flowrates and provide near-real-time verification of fuel quality with on-site hydrogen contaminant detectors (HCDs) for use at both LD and HD stations. The tasks are supported by leading researchers at NREL and coordinating national labs and managed in detail (e.g., schedule, budget, roles, milestones, tasks, reporting requirements) in a hydrogen research consortium project management plan. The UC Davis Institute of Transportation study on hydrogen systems analysis in 2021 is intended to evaluate the current hydrogen polices and their impact on a carbon neutral transportation by 2050 with data analysis and modeling support of the current hydrogen resources.

These efforts are complemented by projects undertaken and supported by the H2FCP and its members over the last few years such as the H2 Fuel Cell Electric Trucks, A Vision for Freight Movement in California – and Beyond document released in July 2021 establishing a vision for 70,000 Class 8 FC trucks supported by 200 hydrogen fueling stations by 2035, including barriers that need to be overcome, CARB's Advanced Clean Truck Regulation adopted in June 2020, and anticipated adoption of the Advanced Clean Fleets Regulation in 2022.

This project area would enable co-funding support for additional or follow on mutually agreed technical tasks with the California Hydrogen Infrastructure Research Consortium members, the H2FCP, UC Davis as well as other collaborative efforts that may be undertaken to advance hydrogen infrastructure technologies including the upcoming hydrogen hubs efforts.

Potential Air Quality Benefits:

The 2022 AQMP identifies the use of alternative fuels and zero emission transportation technologies as necessary to lower Nox and VOC emissions to meet federal air quality standards. One of the major advantages of FCEVs is the fact that they use hydrogen, a fuel that can be domestically produced from a variety of resources such as NG (including biogas), electricity (stationary turbine technology, solar or wind), and biomass. The technology and means to produce hydrogen fuel to support FCEVs are available but require optimization to achieve broad market scale. The deployment of large numbers of FCEVs, which is one strategy to attain air quality goals, requires a well-planned and robust hydrogen fueling infrastructure network. These South Coast AQMD projects, with significant additional funding from other governmental and private entities, will work towards providing the necessary hydrogen production and fueling infrastructure network for our region.

Proposed Project: Develop and Demonstrate MD and HD Fuel Cell Vehicles

Expected South Coast AQMD Cost: $4,800,000

Expected Total Cost: $20,000,000

Description of Technology and Application:

This proposed project would support evaluation, including demonstrating promising fuel cell technologies for applications using direct hydrogen with proton exchange membrane (PEM) fuel cell technology. Battery dominant fuel cell hybrids are another potential technology to reduce costs and potentially enhance the performance of FCEVs.

The California ZEV Action Plan specifies actions to help deploy an increasing number of ZEVs, including MD and HD ZEVs. CARB's Advanced Clean Truck and Fleet and Innovative Clean Transit Bus Regulations will also increase deployment of MD and HD FCVs. Fleets are useful demonstration sites because economies of scale exist in central fueling, training skilled personnel to operate and maintain FCVs, monitoring and collecting data on vehicle performance, and OEM technical and customer support. In some cases, MD and HD FCVs could leverage the growing network of hydrogen stations and provide an early base load of fuel consumption until the number of LD FCVs grows. These vehicles could include hybrid-electric vehicles powered by fuel cells and equipped with batteries capable of being charged from the grid and even supplying power to the grid.

In 2012, the DOE awarded South Coast AQMD funds to demonstrate Zero Emission Container Transport (ZECT) technologies. In 2015, the DOE awarded South Coast AQMD additional funds to develop and demonstrate additional fuel cell truck platforms and vehicles under ZECT II. Both ZECT I and ZECT II enabled the largest strides in Technology Readiness Level (TRL) of hybrid, battery electric and fuel cell HD trucks on the overall vehicle design and architecture. Especially, the fuel cell drayage truck's TRL prior to this project was at a strong Level 4 with several proof-of-concept vehicles constructed and it has advanced the TRL to a Level 7 with ZECT II. The Clean Fuels Program cost-shared the demonstration of transit buses at OCTA which was completed in September 2021. In 2020, the U.S. EPA Targeted Airshed Grant Program awarded South Coast AQMD six fuel cell transit buses to be deployed at SunLine Transit which were also cost-shared by the Clean Fuels Program, Subsequently, in 2023 the U.S. EPA Targeted Airshed Grant Program awarded South Coast AQMD with development and 72eployment of six fuel cell trucks that will also be cost-shared by Clean Fuels Program.

This category may include projects in the following applications:

On-Road:	**Off-Road:**
• Transit Buses • Shuttle Buses • MD & HD Trucks	• Vehicle Auxiliary Power Units • Construction Equipment • Lawn and Garden Equipment • Cargo Handling Equipment

Potential Air Quality Benefits:

The 2022 AQMP identifies the need to implement ZEVs. South Coast AQMD adopted fleet regulations require public and some private fleets within the Basin to acquire alternatively fueled vehicles when making new purchases. CARB is revising the Advanced Clean Fleets for adoption in 2022 to impose 100% zero

emission vehicle fleet targets for last mile delivery, drayage and public fleets in 2035. In the future, such vehicles could be powered by zero emission fuel cells operating on hydrogen fuel. The proposed projects have the potential to accelerate the commercial viability of FCEVs. Expected immediate benefits include the establishment of zero and near-zero emission proof-of-concept vehicles in numerous applications. Over the longer term, the proposed projects could help foster wide-scale implementation of FCEVs in the Basin. The proposed projects could also lead to significant fuel economy improvements, manufacturing innovations and the creation of high-tech jobs in Southern California, besides realizing the air quality benefits projected in the AQMP as well as GHG reductions. Currently, the range of the trucks in the ZECT II project have a targeted range of 150 miles. Future projects would include extending the range of the FCVs up to 400 miles and demonstrate improvements in reliability and durability of powertrain systems and hydrogen storage systems. For fuel cell transit buses, projects are being proposed that reduce the cost of the fuel cell bus to less than $1 million through advanced technologies for the fuel cell stack, higher density and lower cost batteries, and increased production volumes.

Electric / Hybrid Technologies

Proposed Project: Develop and Demonstrate MD and HD On-Road Battery Electric Vehicles and Equipment

Expected South Coast AQMD Cost: $4,800,000

Expected Total Cost: $255,500,000

Description of Technology and Application:

The South Coast AQMD has long been a leader in promoting early demonstrations of next generation LD vehicle propulsion technologies (and fuels). However, given the commercial availability of LD EVs and relatively low LDV emissions inventory, priorities have shifted. South Coast AQMD will continue to evaluate market offerings and proposed technologies in LD vehicles to determine if any future support is required.

Meanwhile, MD and HD vehicles only make up 5[20] percent of vehicles in the U.S. and drive 11[21] percent of all vehicle miles traveled each year and yet are responsible for more than 30[22] percent of all the fuel burned annually. Moreover, the 2022 AQMP identified MD and HD vehicles as the largest source of NOx emissions in the Basin. Electric and hybrid technologies have gained momentum in the LD sector with commercial offerings by most of the automobile manufacturers. Unfortunately, given the advances in LD sector, significant emission reductions are still needed for MD and HD vehicles and off-road equipment, exacerbated by low turnover of these vehicles by fleets and high incremental costs for battery and hybrid electric vehicles and equipment compared to conventional-fueled vehicles and equipment.

South Coast AQMD has investigated the use of electric and hybrid technologies to achieve similar performance as conventional-fueled counterparts while achieving emission reductions and improved fuel economy. Multiple NG and diesel hybrid vehicles have been developed and demonstrated under the DOE funded Zero Emissions Cargo Transport (ZECT), CARB Greenhouse Gas Reduction Fund (GGRF) and NREL's Natural Gas Vehicle Research Consortium. These hybrid trucks all share plug-in capability and ability to operate in zero emission mode, and some leveraging advanced concepts such as geofencing and EcoDrive to maximize emission reductions in disadvantaged communities. CARB ACT and ACF regulations further provided additional compliance flexibility for plug-in hybrids with zero emission range. Battery electric-powered trailers is under development, which can integrate with existing diesel and zero-emission tractors. The electric-powered trailer can provide propulsion assistance and/or regenerative braking, and thus results in immediate emission reductions for diesel tractors and range extension of new zero-emission tractors. Vehicle based hybrid systems continue to progress for additional emission reductions and efficiency improvements. Engine powertrain based hybrid systems also began to emerge.

Vehicle categories to be considered for potential or future demonstration and deployment projects include drayage/freight/regional haul trucks, utility trucks, last mile delivery vans, shuttle buses, transit buses, waste haulers, construction equipment, cranes and other off-road equipment such as yard tractors, forklifts, top handlers, and RTG cranes. Innovations that may be considered for demonstration and deployment include

[20] https://www.bts.gov/content/number-us-aircraft-vehicles-vessels-and-other-conveyances

[21] https://www.bts.gov/content/us-vehicle-miles

[22] https://www.bts.gov/content/fuel-consumption-mode-transportation

advancements in the auxiliary power unit, either ICE or other heat engine; and battery-dominant plug-in hybrid systems utilizing off-peak charging, with advanced battery technologies including alternative chemistries, design, and management systems. Alternative fuels are preferred in these projects, e.g., natural gas, especially from renewable sources, LPG, hydrogen, gas-to-liquid (GTL) and hydrogen-natural gas blends, but conventional fuels such as gasoline, renewable diesel, or even modified biodiesel may be considered if emission benefits can be demonstrated as equivalent or superior to alternative fuels. Both new designs and retrofit technologies and related charging infrastructure will be considered.

Both on-road vehicles and off-road equipment are transitioning increasingly towards zero emission technologies. Off-road equipment includes cargo handling equipment as well as construction equipment. The JETSI Pilot Project included deployment of 100 Daimler and Volvo Class 8 BETs and the Volvo LIGHTS project included deployment of 30 Volvo Class 8 BETs and 29 battery electric yard tractors and forklifts,. Volvo Construction Equipment just recently finished demonstrating a small battery electric compact excavator and wheel loader in California that was commercially released in late 2021. Several other manufacturers have released battery electric and hybrid equipment, and more are becoming commercially available. CARB has introduced the Clean Off-Road Equipment Voucher Incentive Project (CORE) which have been seeing great success in deploying zero-emission cargo handling equipment and switcher locomotives. The most recent round of funding in 2022 also included off-road construction equipment. Since the applications are more diverse in this sector, continued development and incentives are needed to accelerate progress in this sector, especially for large mobile off-road equipment where infrastructure solutions are more difficult that will require alternative charging solutions (ACS).

This project category will develop and demonstrate:

- various electric vehicles and equipment;
- studies for anticipated costs for electric vehicles and equipment;
- customer interest and preferences for these alternatives;
- integration of technologies into prototype vehicles and fleets;
- battery electric and hybrid-electric MD and HD vehicles (e.g., drayage/freight/regional haul trucks, utility trucks, delivery vans, shuttle buses, transit buses, waste haulers);
- development and demonstration of battery electric off-road equipment, (e.g., battery electric off-road cargo handling such as yard tractors, forklifts and top-handlers, and construction equipment; and
- development and demonstration of hybrid and plug-in hybrid vehicle technology.

Potential Air Quality Benefits:

The 2022 AQMP identifies zero or near-zero emission vehicles as a key attainment strategy. Plug-in hybrid electric technologies have the potential to achieve near-zero emission while retaining the range capabilities of conventional-fueled vehicles, a key factor expected to enhance broader consumer acceptance. Given the variety of EV systems under development, it is critical to determine actual emission reductions and performance metrics compared to conventional-fueled vehicles. Successful demonstration of optimized prototypes would promise to enhance the deployment of zero and near-zero emission technologies.

Expected benefits include the establishment of criteria for emission evaluations, performance requirements, and customer acceptability of the technology. This will help both regulatory agencies and OEMs to expedite introduction of zero and near-zero emission vehicles in the Basin, which is a high priority of the 2022 AQMP.

Proposed Project: Demonstrate Light-Duty Battery Electric Vehicles and Plug-In Hybrid Vehicles

Expected South Coast AQMD Cost: $160,000

Expected Total Cost: $160,000

Description of Technology and Application:

Zero Emission Infrastructure South Coast AQMD has included BEVs and PHEVs as part of its demonstration fleet since the development of early conversion vehicles. South Coast AQMD installed 92 Level 2 EV charging ports in 2017 and a DC fast charger with CHAdeMO and CCS1 connectors in 2018 to support public and workplace charging as a means of education outreach regarding BEV and PHEV technology. Thirty networked Level 2 fleet chargers were added through the Southern California Edison Charge Ready Fleet program in 2020, which will help South Coast AQMD acquire 8,500 GVW and over ZEVs like LD trucks and vans to comply with the upcoming CARB Advanced Clean Fleet regulation.

LD BEVs and PHEVs are available from most established OEMs and several new OEMs. Current legislation extends solo carpool lane access only for MY 2019 and later vehicles, with all Clean Air Vehicle decals expiring between 2023 – 2025, unless legislation is adopted to continue.

Potential Air Quality Benefits:

The 2022 AQMP identifies the need to implement LD EVs. South Coast AQMD adopted fleet regulations require public and some private fleets within the Basin to acquire alternatively fueled vehicles when making new purchases. In the future, such vehicles could be powered by BEVs. The proposed projects have the potential to accelerate commercial viability of BEVs and PHEVs. Expected immediate benefits include the deployment of ZEVs in South Coast AQMD's demonstration fleet. Over the longer term, the proposed projects could help foster wide-scale implementation of ZEVs in the Basin. The proposed projects could also lead to significant fuel economy improvements, manufacturing innovations and the creation of high-tech jobs in Southern California, besides realizing the air quality benefits projected in the 2022 AQMP.

Stationary Clean Fuel Technologies

Proposed Project: Develop and Demonstrate Microgrids with Photovoltaic/Fuel Cell/Battery Storage Energy Management

Expected South Coast AQMD Cost: $1,000,000

Expected Total Cost: $4,000,000

Description of Technology and Application:

CARB has proposed the Advanced Clean Truck Regulation which is part of a holistic approach to accelerate a large-scale transition of zero emission MD and HD vehicles from Class 2B to Class 8. Manufacturers who certify Class 2B-8 chassis or complete vehicles with combustion engines would be required to sell zero emission trucks as an increasing percentage of their annual California sales from 2024 to 2030. By 2030, zero emission truck/chassis sales would need to be 50 percent of Class 4–8 straight trucks sales and 15 percent of all other truck sales.

The commercialization of zero emission HD trucks Is currently under way with two of the largest manufacturers offering commercial products in California. Both Daimler and Volvo obtained CARB certification of their Class 6 and/or 8 battery electric trucks (BETs) in 2020, with these trucks eligible for HVIP and other incentives and commercially available for sale. South Coast AQMD also received $16M in CARB and $11M in CEC funding, as well as $34M in co-funding from project partners for the deployment of 100 Daimler and Volvo Class 8 BETs, solar, and energy storage for the JETSI Pilot Project for drayage and regional haul applications. Ever larger deployments of zero emission trucks will be needed for the technology to have an impact on air quality.

Large deployments of zero emission Class 8 BETs each carrying 300+ kWh of battery-stored energy or fuel cell trucks (FCTs) carrying 30-50 kg of hydrogen will require costly infrastructure that creates a barrier for some fleets to adopt zero emission technologies. Many fleet operators lease their facilities making the capital expenditure of EV or hydrogen infrastructure impossible to recoup in a short period of time. To comply with existing and upcoming regulatory requirements, fleets are having to navigate challenges in installing and maintaining charging and/or fueling infrastructure. Microgrids can be instrumental in meeting the challenge of providing large amounts of energy cost-effectively for EV charging or hydrogen generation to support zero emission vehicle charging and fueling. Additionally, if the microgrid equipment is owned by a third party and energy is sold to the fleet through a power purchase agreement, the financial challenge of large capital investment can be avoided by the fleets.

A microgrid Is a group of Interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected and island-mode. Microgrids can work synergistically with the utility grid to provide power for zero emission vehicle fueling by managing when energy from the grid is used–during off-peak hours when it is the least expensive. Then during peak demand periods, the microgrid would use energy from battery storage or onsite generation. Most technologies that make up microgrids include photovoltaic, fuel cells, battery storage, along with hardware and software for the energy management system (EMS). When grid service is interrupted, the microgrid can disconnect from and continue to operate as an energy island independent from the grid. Having assurance of an uninterrupted power source is an important consideration for fleets. If the microgrid is connected to the fleet's logistics and telematics systems, additional benefits in terms of infrastructure cost and battery life for BETs

can be realized. If the EMS is fed information on the route a truck is planning to travel, it can charge the vehicle with enough energy for the trip so the truck will operate within the desired 20-80 percent state of charge (SOC) of the battery having the least amount of impact to battery life. Additionally, if the EMS is connected to the logistics system, it can plan charging schedules with 150 kW or lower power chargers which will have less impact on battery life than 350+ kW chargers and lower charging costs.

Electricity demand of electric and fuel cell HD trucks is substantial. For a 100-vehicle fleet of BETs with 300 kWh batteries, 30 MW hours/day of electricity would be required to charge these BETs. For a 100-vehicle fleet of FCTs the hydrogen requirement is 2,000 kg/day. Microgrids can provide energy for EV and hydrogen infrastructure to enable large zero emission vehicle deployments and make charging and fueling economical and reliable. Staff has demonstrated several microgrid projects with University of California Irvine and has toured the microgrid at University of California San Diego. Currently, several pilot projects are being discussed with microgrid developers and fleets that involve various configurations of microgrid technologies and different business models. Proposed projects would include development and demonstration of microgrids utilizing various types of renewable and zero emitting onsite generation (fuel cell tri-generation, power to gas, photovoltaic, wind), energy storage, connectivity to logistics systems, vehicle-to-grid and vehicle-to-building technologies. Projects that demonstrate different business models will be considered, such as projects involving a separate entity owning some or all the microgrid equipment and engaging in a power purchase agreement to provide energy to fleets transitioning to zero emission trucks. Proposed projects would partner with truck OEMs and their major customers, such as large- and medium-sized fleets looking at microgrid solutions for their operations in the Basin.

Potential Air Quality Benefits:

Microgrids can provide grid resilience and potentially support large deployments of zero emission MD and HD trucks that are necessary to meet the AQMP target of 83 percent NOx emission reductions from the 2018 level and 67 percent additional reductions in 2037 beyond already adopted regulations and programs by 2037. Both renewable and zero emitting power generation technologies that make up a microgrid can provide a well-to-wheel zero emission pathway for transporting goods. Projects could potentially reduce a significant class of NOx and CO emissions in excess of the assumptions in the 2022 AQMP and further enhance South Coast AQMD's ability to enforce full-time compliance.

Proposed Project: Develop and Demonstrate Zero or Near-Zero Emission Energy Generation Alternatives

Expected South Coast AQMD Cost: $2,500,000

Expected Total Cost: $7,000,000

Description of Technology and Application:

The objective of this project is to support development and demonstration of clean energy, renewable alternatives in stationary applications. The technologies to be considered include thermal, photovoltaic and other solar energy technologies; wind energy systems; energy storage potentially including vehicle to grid or vehicle to building functionalities for alternative energy storage; biomass conversion; and other renewable energy and recycling technologies. Innovative solar technologies, such as solar thermal air conditioning and photovoltaic-integrated roof shingles, are of particular interest. Also, in the agricultural sections of the Basin, wind technologies could potentially be applied to drive large electric motor-driven pumps to replace highly polluting diesel pumps. Besides renewable technologies, electrolyzer technology could be used to generate hydrogen as a clean fuel. Hydrogen, when used in ICEs, can potentially reduce tail-pipe emissions of NOx, while in fuel cells emissions are reduced to zero.

This project is expected to result in pilot-scale production demonstrations, scale-up process design and cost analysis, overall environmental impact analysis and projections for ultimate clean fuel costs and availability. This project is expected to result in several projects addressing technological advancements in these technologies that may improve performance and efficiency, potentially reduce capital and operating costs, enhance the quality of NG generated from renewable sources for injection into NG pipelines, improve reliability and identify markets that could expedite implementation of successful technologies.

Potential Air Quality Benefits:

The 2022 AQMP identifies that the development and implementation of non-polluting power generation could gain maximum air quality benefits. Polluting fossil fuel-fired electric power generation needs to be replaced with clean, renewable energy resources or other advanced zero emission technologies, such as hydrogen fuel cells, particularly in a distributed generation context to help provide grid resiliency as the transportation sector becomes more reliant on electricity.

This project is expected to accelerate implementation of advanced zero emission energy sources. Expected benefits include directly reducing emissions by displacement of fossil generation; proof-of-concept and potential viability for zero emission power generation systems; increased exposure and user acceptance of the new technology; reduced fossil fuel usage; and potential for increased use, once successfully demonstrated, with resulting emission benefits, through expedited implementation. These technologies would also have a substantial influence in reducing GHG emissions.

Fuel and Emissions Studies

Proposed Project: Conduct In-Use Emission Studies including MATES VI for Advanced Technology Vehicle Demonstrations

Expected South Coast AQMD Cost: $1,000,000

Expected Total Cost: $4,000,000

Description of Technology and Application:

Hybrid electric, hybrid hydraulic, plug-in electric hybrid and battery-electric and fuel cell electric vehicles will all play a role in the future of transportation. Each of these transportation technologies has attributes that could provide unique benefits to different transportation sectors. Identifying optimal placement of each transportation technology will provide the co-benefits of maximizing environmental benefit and return on investment.

In the past two decades, South Coast AQMD has been supporting rapid deployment of near-zero emission NG technologies since 2015. As more near-zero emission natural gas, propane and other alternative fuel technologies penetrate different segments, in-use assessment of real-world benefit is needed to monitor the impact of these vehicles.

The CARB EMFAC 2017 model that the 2022 AQMP is has a relatively limited data set for alternative fuel vehicles. For the latest EMFAC 2021, more complete NG engine modules have been included for the first time with emissions data gathered recently completed 200 vehicle in-use emissions study. In addition to the natural data, the 200-vehicle data also provided key inputs for the activity updates from the EMFAC model in the region. As the new CARB and U.S. EPA low-Nox regulations focus on addressing the gap of in-use and certification values, staff expects the in-use emissions from new engines to perform closer to certification values, I but there are still a significant population of the MY 2010+ legacy fleet expected to remain in service well into the 2030s. There is always a need to better assess real world truck emissions, fuel economy, and activity from engines, hybrid powertrain and zero emission technologies for continued technology improvements and verification of emission reductions.

This project would review and potentially coordinate application specific drive cycles for specific applications. Potential emission reductions and fossil fuel displacement for each technology in a specific application would be quantified on a full-cycle basis. This information could be used to develop a theoretical database of potential environmental benefits of different transportation technologies when deployed in specific applications. This duty-cycle requirement, often based on traditional vehicles, is used for planning purposes for building MD and HD public zero emission vehicle fueling stations, similar to the approaches provided for NREL's fleet DNA database. Furthermore, the creation and standardization of test cycles, like the chassis dyno-based cycle, can be used to evaluate efficiency of zero-emissions vehicles and direct comparisons with baseline ICE vehicles.

Another project would be characterization of intermediate volatility organic compound (IVOC) emissions, which is critical in assessing ozone and secondary organic aerosol (SOA) precursor production rates. Diesel vehicle exhaust and unburned diesel fuel are major sources and contribute to formation of urban ozone and SOA, which is an important component of PM2.5. NGVs are also a concern due to lack of particulate filters, however the actual impact based on current and projected vehicle populations needs to be further studied. Another emerging PM emissions of interest non-tailpipe emissions from brake and tire wear. CARB estimates

PM from non-tailpipe sources already exceeded traditional sources and increase with VMT. CARB has introduced a series of projects to assess the emission factor for brake- and tire-wear emissions. South Coast also expects new projects to support the research needed for MATES VI study.

Potential Air Quality Benefits:

Development of an emissions reduction database for various application specific transportation technologies would assist in targeted deployment of new transportation technologies. This database coupled with application specific vehicle miles traveled and population data would assist in intelligently deploying advanced technology vehicles to attain the maximum environmental benefit. These two data streams would allow vehicle technologies to be matched to an application that is best suited to the specific technology, as well as selecting applications that are substantial enough to provide significant environmental benefits. Demonstration of a quantifiable reduction in operating cost through intelligent deployment of vehicles will also accelerate commercial adoption of various technologies. Accelerated adoption of lower emitting vehicles will further assist goals in the 2022 AQMP.

Proposed Project: Conduct Emission Studies including MATES VI on Biofuels, Alternative Fuels and Other Related Environmental Impacts

Expected South Coast AQMD Cost: $1,00,000

Expected Total Cost: $4,000,000

Description of Technology and Application:

The use of renewable fuels such as biofuels can be an important strategy to reduce petroleum dependency, air pollution and greenhouse gas (GHG) emissions and help with California's aggressive GHG reduction goals. Biofuels are receiving increased attention due to national support and state activities resulting from SB 32, AB 1007 and the Low-Carbon Fuel Standard. With an anticipated increase in renewable fuel use, it is the objective of this project to further analyze these fuels to better understand their benefits and impacts not only on GHGs but also air pollution and associated health effects.

In various diesel engine studies, replacement of petroleum diesel fuel with renewable fuel has demonstrated reduced PM, CO and air toxics emissions. Renewable fuel also has the potential to reduce GHG emissions if made from renewable feedstocks such as soy and canola. However, certain blends of biodiesel can increase NOx emissions for some engines and duty cycles, which exacerbates ozone and PM2.5 challenges faced in the Basin. In addition, despite recent advancements in toxicological research in the air pollution field, the relationship between biodiesel particle composition and associated health effects is still not completely understood.

Ethanol is another biofuel that is gaining increased national media and state regulatory attention. CARB's reformulated gasoline regulation increases ethanol content to 10 percent as a means to increase the amount of renewable fuels in the state. As in the case of biodiesel, ethanol has demonstrated in various emission studies to reduce PM, CO and toxic emissions. South Coast AQMD also has been monitoring efforts in using ethanol as a primary fuel for MD and HD applications in optimized engine systems that allows both criteria and GHG reductions which could be another pathway for reducing emissions due to abundance of ethanol from the light duty sector.

CARB recently proposed a regulation on commercialization of alternative diesel fuels, including biodiesel and renewable diesel, while noting that biodiesel in older HD vehicles can increase NOx. The need for emerging alternative diesel fuels for HD trucks and transit buses is also being studied. Researchers have proposed evaluating the emissions impact of RNG and other NG blends such as renewable hydrogen or pure hydrogen.

To address these concerns on potential health effects associated with alternative fuels and fuel blends, this project will investigate physical and chemical composition and associated health effects of tailpipe PM emissions from LD to HD vehicles burning biofuels to ensure public health is not adversely impacted by broader use of these fuels. This project also supports future studies to identify mitigation measures to reduce NOx emissions from biofuels. Additionally, a study of well-to-wheel emissions from for the extraction and use of shale gas might be considered.

The Power-to-Gas concept as well as demand for additional green hydrogen supply has renewed interest in hydrogen-fossil fuel blends as well as pure hydrogen for use in both ICE and other combustion sources. Hydrogen fueled ICEs were studied heavily in the early 2000s and results have shown significant possible

criteria emission reductions with optimized engine calibration though any new hydrogen ICE will need to comply to the latest standard for MY 2024 and MY 2027

To evaluate contribution of meteorological factors to high ozone and PM2.5 episodes occurring in the Basin, mainly as a result of higher summer temperatures and increased air stagnation following droughts, a comprehensive study is necessary to evaluate trends of meteorological factors that may adversely impact air quality in the Basin. The study will assist in better understanding potential impact of recent weather trends on criteria pollutant emissions and developing more effective strategies for improving air quality in the future.

Potential Air Quality Benefits:

If renewable diesel, biodiesel and biodiesel blends can be demonstrated to reduce air pollutant emissions with the ability to mitigate NOx impacts, this technology will become a viable strategy in meeting air pollutant standards as well as the goals of SB 32 and the Low-Carbon Fuel Standard. The use of biodiesel is an important effort for a sustainable energy future. Emission studies are critical to understanding emission benefits and any tradeoffs (NOx impacts) that may result from using this alternative fuel. With reliable information on the emissions from using biodiesel and biodiesel blends, this can ensure the use of biodiesel without creating additional NOx emissions. Additionally, understanding meteorological factors on criteria pollutant emissions may help identify mitigation strategies, possibly through targeted advanced transportation deployment.

Proposed Project: Identify and Demonstrate In-Use Fleet Emission Reduction Technologies and Opportunities

Expected South Coast AQMD Cost: $400,000

Expected Total Cost: $1,500,000

Description of Technology and Application:

New technologies, such as alternative fueled HD engines, are extremely effective at reducing emissions because they are designed to meet the most stringent emissions standards while maintaining vehicle performance. In addition, many new vehicles are now equipped with telematics enabling motorists to obtain transportation information such as road conditions to avoid excessive idling and track information about vehicle maintenance needs, repair history, tire pressure and fuel economy. Telematics have been shown to reduce emissions from new vehicles through various vehicle usage optimization strategies. Unfortunately, many in-use fleets lack telematic systems, particularly HD engines in trucks, buses, construction equipment, locomotives, commercial harbor craft and cargo handling equipment, and have fairly long working lifetimes (up to 20 years due to remanufacturing in some cases). Even LD vehicles routinely have lifetimes exceeding 200,000 miles and 10 years. The in-use fleet, especially the oldest vehicles, are responsible for the majority of emissions. In the last few years, real-time emissions and fuel economy data reporting along with telematics has been demonstrated with large fleets as fleet management tools to identify high emitters and increase operational efficiency. Similar efforts have already been proposed by CARB as part of the HD I/M regulation. Moreover, the same telematic systems are being installed on zero emission trucks where fleet and charging management are important. Cloud based fleet management concepts are being proposed by researchers to maximize range and air quality benefits of zero emission trucks.

This project category is to investigate near-term emission control technologies that can be cost-effectively applied to reduce emissions from the in-use fleet. The first part of the project is to identify and conduct proof-of-concept demonstrations of feasible candidate technologies, such as:

- remote sensing for HD vehicles including license plate recognition systems;
- annual testing for high mileage vehicles (>100,000 miles);
- replace or upgrade emission control systems at 100,000-mile intervals;
- on-board emission diagnostics with remote notification;
- low-cost test equipment for monitoring and identifying high emitters;
- test cycle development for different class vehicles (e.g. four-wheel drive SUVs);
- electrical auxiliary power unit replacements;
- development, deployment and demonstration of smart vehicle telematic systems;
- fleet and charger management concepts; and
- low cost NOx sensor development.

Potential Air Quality Benefits:

Many of the technologies identified can be applied to LD and HD vehicles to identify and subsequently remedy high-emitting vehicles in the current fleet inventory. Estimates suggest that 5 percent of existing fleets account for up to 80 percent of the emissions. Identification of higher emitting vehicles would assist with demand-side strategies, where higher emitting vehicles have correspondingly higher registration

charges. Identification and replacement of high-emitting vehicles has been identified in the Community Emission Reduction Plans (CERPs) from multiple AB 617 communities as a high priority for residents living in these communities, particularly as HD trucks frequently travel on residential streets to bypass traffic on freeways surrounding these disadvantaged communities.

Renewable Fuel Infrastructure

Proposed Project: Demonstrate Low-Emission Engine/Generation Technology

Expected South Coast AQMD Cost: $1,000,000

Expected Total Cost: $2,000,000

Description of Technology and Application:

Natural gas vehicles (NGVs) have been very successful in reducing emissions in the Basin due to the deployment by fleet owners and operators of HD vehicles utilizing this fuel. Currently, an increasing number of on-road HD NG engines are being certified to CARB's optional low-NOx standards which are significantly lower in NOx emissions than the current on-road HD standard. This technology category seeks to support the expansion of OEMs producing engines or systems certified to the lowest optional NOx standard or near-zero emission and useable in a wide variety of MD and HD applications, including Class 6 vehicles such as school buses and in passenger and goods delivery vans, Class 7 vehicles such as transit buses, waste haulers, street sweepers, sewer-vector trucks, dump trucks, concrete mixers, commercial box trucks, Class 8 tractors used in goods movement and drayage operations, and off-road equipment such as construction vehicles and yard hostlers. This category can also include advancing engine technologies to improve engine efficiencies that will help attract HD vehicle consumers to NGVs. Under Engine Systems, South Coast AQMD supports efforts for development of high-powered NGVs to support long-haul applications. Increasing NG engine availability for the full range of applications would increase NGV deployment in long-haul applications where diesel engines have been the only feasible option.

Hydrogen fueled internal combustion engines starts to gain more attentions as a few advantages exist with this technology. Comparing with the fuel cell electric technology, hydrogen ICE can work at a lower level of purity and costs less. It can also be a drive force for the fuel cell battery application by increasing the consumption of hydrogen fuel in the transportation sector. Hydrogen ICE shares similarities with traditional ICE. The development cycle is relatively short. Efforts have been put on to optimize tailpipe NOx emissions, while greenhouse gas (GHG) emissions are zero.

Potential Air Quality Benefits:

NGVs have inherently lower engine criteria pollutant emissions relative to conventionally fueled vehicles, especially older diesel-powered vehicles. Recently, on-road HD engines have been certified to near-zero emission levels that are 90% lower in NOx than the current on-road HDV standard. California's On-Road Truck and Bus Regulation requires all on-road HDVs to meet the current standard by January 1, 2023. The deployment of near-zero emission vehicles would significantly further emission reductions relative to the state's current regulatory requirements. Incentivizing the development and demonstration of near-zero emission NGVs in private and public fleets, goods movement applications, and transit buses will help reduce local emissions and emissions exposure to nearby residents. NGVs can also have lower GHG emissions and increase energy diversity, help address national energy security objectives, and reduce biomass waste produced from such feedstocks. Deployment of additional NGVs is consistent with the 2022 AQMP goal to reduce criteria pollutants. When fueled by RNG, it supports California's objectives of reducing GHGs and carbon intensity of the state's transportation fuel supply, as well as the federal government's objective of increasing domestically produced alternative transportation fuels.

Proposed Project: Develop, Maintain and Expand Renewable Fuel Infrastructure

Expected South Coast AQMD Cost: $300,000

Expected Total Cost: $1,000,000

Description of Technology and Application:

This project supports the development, maintenance and expansion of NG fueling infrastructure in strategic locations throughout the Basin, including the Ports, and advancing technologies and station design to improve fueling and fueling efficiencies of HD NGVs. This category supports broader deployment of near-zero emission HD vehicles and implementation of South Coast AQMD's fleet rules. In addition, as NG fueling infrastructure begins to age or has been placed in demanding usage, components will deteriorate. This project offers facilities the opportunity to replace worn-out equipment or to upgrade existing fueling and/or garage and maintenance equipment to provide increased fueling capacity to public agencies, private fleets and school districts.

Potential Air Quality Benefits:

The 2022 AQMP identifies the use of alternative clean fuels in mobile sources as a key attainment strategy. HD NGVs have significantly lower emissions than their diesel counterparts and represent one of the cleanest ICE-powered vehicles available today. The project has the potential to significantly reduce the installation and operating costs of NGV fueling infrastructure and improve vehicle fueling times through improved fueling system designs and high-flow nozzles. New or improved NGV infrastructure helps facilitate near-zero emission NGVs in private and public fleets. It is expected that the lower fuel cost of NG relative to diesel and added financial incentives of RNG under the state's Low Carbon Fuel Standard (LCFS) program attract fleets and consumers to this technology. Increased exposure and fleet and consumer acceptance of NGVs will lead to significant and direct reductions in NOx, VOC, CO, PM and toxic compound mobile source emissions. Such increased penetration of NGVs will provide direct emission reductions of NOx, VOC, CO, PM and air toxic compounds throughout the Basin.

Proposed Project: Demonstrate Renewable Transportation Fuel Production and Distribution Technologies

Expected South Coast AQMD Cost: $400,000

Expected Total Cost: $1,500,000

Description of Technology and Application:

The transportation sector represents a significant source of criteria pollution in the Basin. Clean, alternative fuel-powered transportation is a necessary component for this region to meet NAAQS. Alternative fuels produced from renewable sources such as waste biomass help further efforts associated with landfill and waste diversion, GHG reduction, energy diversity and petroleum dependency. Locally produced renewable fuels further reduce concerns associated with out-of-state production and transmission of fuel and help support the local economy. Renewable fuels recognized as a transportation fuel under the state's LCFS program and the federal government's Renewable Fuel Standard program can provide financial incentives, including reduced fuel price and operational costs, which act as incentives to purchase and deploy alternative or renewable energy powered vehicles.

This project category will consider development and demonstration of technologies for the production and use of renewable transportation fuels such as RNG, renewable diesel (RD), and renewable hydrogen (RH). These renewable fuels can be converted from various waste biomass feed stocks, including municipal solid wastes, green waste, and biosolids produced at wastewater treatment facilities generated from anaerobic digestion, gasification, and pyrolysis.

The main objectives of this project are to investigate, develop and demonstrate:

- commercially viable methods for converting renewable feed stocks into CNG, LNG, hydrogen or diesel (e.g., production from biomass);
- economic small-scale NG liquefaction technologies;
- utilization of various gaseous feed stocks locally available;
- commercialize incentives for fleets to site, install and use RNG refueling facilities; and
- pipeline interconnection in the local gas grid to supply users.

Potential Air Quality Benefits:

The 2022 AQMP relies on a significant increase in the penetration of zero and near-zero emission vehicles in the Basin to attain the NAAQS by 2037. This project would help develop renewable transportation fuel production and distribution facilities to improve local production and use of renewable fuels to help reduce transportation costs and losses as well as reduce total operating costs of zero and near-zero emission vehicles to be competitive with comparable diesel fueled vehicles. Such advances in production and use are expected to lead to greater infrastructure development. Additionally, this project could support the state's goal of redirecting biomass waste for local fuel production and reduce GHGs associated with these waste biomass feedstocks.

Health Impacts Studies

Proposed Project: Source Specific Particulate Matter Impacts for MATES VI

Expected South Coast AQMD Cost: $1,000,000

Expected Total Cost: $1,250,000

Description of Technology and Application:

Reducing diesel exhaust from vehicles has become a high priority in the Basin since CARB identified the particulate phase of diesel exhaust as a surrogate for all toxic air contaminants emitted from diesel exhaust. Additionally, health studies indicate that ultrafine particulate matter (UPM) may be more toxic on a per-mass basis than other fractions. Several control technologies have been introduced and others are under development. Recent studies have shown that control technologies applied to mobile sources have been effective in reducing the mass of particulates emitted. However, there is also evidence that UPM on and near roadways has increased, even while the mass of particulates has decreased. To have a better understanding of changes in ultrafine particulate emissions from the application of new technologies and health effects of these emissions, an evaluation and comparison of UPM and potential impacts on community exposure, particularly in disadvantaged communities, is needed.

In this project, measurements and chemical composition of UPM will be done, as well as studies conducted from HD vehicles to measure, evaluate and compare UPM, PAH and other relevant toxic emissions from different types of fuels such as gasoline, CNG, low-sulfur diesel, biofuels and others. This project needs to be closely coordinated with development of technologies for alternative fuels, aftertreatment technologies, and new engine development to determine health benefits of such technologies.

Furthermore, gasoline direct injection (GDI) vehicles are known for higher efficiency and power output but the PM emissions profile is not well understood especially on secondary organic aerosol (SOA) formation potential. As manufacturers introduce more GDI models in the market to meet new fuel economy standards, it is important to understand SOA potential from these vehicles as it could further impact ambient PM concentration in our region. In 2015 a project with UCR CE-CERT to investigate the physical and chemical composition of aerosols from GDI vehicles using a mobile environmental chamber was designed and constructed to characterize secondary emissions. Based on initial results indicating an increase in particle numbers, follow-up in-use studies to assess PM emissions including with and without particle filters will be beneficial. Similar studies should also be conducted on NG MD and HD vehicles to understand potential emissions impacts are being considered.

Potential Air Quality Benefits:

The 2022 AQMP for the Basin relies on significant penetration of low emission vehicles to attain federal clean air standards. Reduction of PM emissions from combustion of diesel and other fuels is a major priority in achieving these standards. This project would help to better understand the nature and number of UPM generated by different types of fuels and advanced control technologies as well as provide information on potential health effects of UPM. Such an understanding is important to assess the emission reduction potentials and health benefits of these technologies. In turn, this will have a direct effect on the policy and regulatory actions for commercial implementation of alternative fuel vehicles in the Basin.

Proposed Project: Conduct Monitoring to Assess Environmental Impacts including MATES VI

Expected South Coast AQMD Cost: $200,000

Expected Total Cost: $800,000

Description of Technology and Application:

Facilities, buildings, structures, or highways which attract mobile sources of pollution are considered "indirect" sources. Ambient and saturation air monitoring near sources such as ports, airports, rail yards, freight/logistics distribution centers and freeways is important to identify emissions exposure to surrounding communities and provide data to assess health impacts. This could include the study of indirect sources such as warehouses which are impacted by South Coast AQMD's Indirect Source Regulations. This project category would identify areas of interest and conduct ambient air monitoring, emissions monitoring, analyze data and assess potential health impacts from mobile sources. These projects would need to be at least one year in duration to properly assess air quality impacts in surrounding communities.

Potential Air Quality Benefits:

The proposed project will assist in evaluation of adverse public health impacts associated with mobile sources. The information will be useful in (a) determining whether indirect sources have a relatively higher impact on residents living in close proximity, particularly in disadvantaged communities; and (b) providing guidance to develop some area-specific control strategies in the future should it be necessary.

Proposed Project: Assess Sources and Health Impacts of Particulate Matter including MATES VI

Expected South Coast AQMD Cost: $200,000

Expected Total Cost: $800,000

Description of Technology and Application:

Previous studies of ambient levels of toxic air contaminants, such as the MATES studies, have found that diesel exhaust is the major contributor to health risk from air toxics. Analyses of diesel particulate matter (DPM) in ambient samples have been based on measurements of elemental carbon. While the bulk of particulate elemental carbon in the Basin is thought to be from combustion of diesel fuels, it is not a unique tracer for diesel exhaust.

The MATES III study collected particulate samples at ten locations in the Basin. Analysis of particulate bound organic compounds was utilized as tracers to estimate levels of ambient DPM as well as estimate levels of PM from other major sources. Other major sources that were taken into consideration include automobile exhaust, meat charbroiling, road dust, wood smoke and fuel oil combustion. Analyzing for organic compounds and metals in conjunction with elemental carbon upon collected particulate samples was used to determine contributing sources.

MATES IV, completed in 2015, included an air monitoring program and updated emissions inventory of toxic air contaminants. MATES IV also measured UPM concentrations and black carbon at monitoring sites as well as near sources such as airports, freeways, rail yards, busy intersections and freight/logistics warehouse operations.

South Coast AQMD completed MATES V in August 2021 to update the emissions inventory of toxic air contaminants, as well as modeling to characterize risks, including measurements and analysis of ultrafine particle concentrations typically emitted or subsequently formed from vehicle exhaust. Findings from the MATES V report showed that air toxics cancer risk based on modeling data has decreased by about 50% since MATES IV, with average multi-pathway air toxics cancer risk at 454-in-a-million. The highest risk locations are at LAX and the Ports along goods movement and transportation corridors. Diesel PM continues to be the major contributor accounting for over 60% of the overall air toxics cancer risk. For the first time, chronic non-cancer risk was estimated with a chronic hazard index of 5.9 across the 10 stations in the MATES V study. The MATES VI study is in the planning stages with monitoring scheduled to start in summer 2025.

This project category would include other related factors, such as toxicity assessment based on age, source (HD, LD engines) and composition (semi-volatile or non-volatile fractions) to better understand health effects and potential community exposure, particularly in disadvantaged communities. Additionally, early identification of new health issues could be of considerable value and could be undertaken in this project category.

Potential Air Quality Benefits:

Results of this work will provide a more robust, scientifically sound estimate of ambient levels of DPM as well as levels of PM from other significant combustion sources, including gasoline and diesel generated VOCs. This will allow a better estimation of potential exposure and health effects from toxic air contaminants from diesel exhaust in the Basin. This information in turn can be used to determine health benefits of promoting clean fuel technologies.

Technology Assessment and Transfer/Outreach

Proposed Project: Assess and Support Advanced Technologies and Disseminate Information

Expected South Coast AQMD Cost: $600,000

Expected Total Cost: $1,000,000

Description of Project:

This project supports assessment of clean fuels and advanced technologies, progress towards commercialization and dissemination of information on demonstrated technologies. The objective of this project is to expedite transfer of technology developed from Technology Advancement Office projects to the public domain, industry, regulatory agencies and the scientific community. This project is a fundamental element in South Coast AQMD's outreach efforts by coordinating activities with other organizations to expedite implementation of advanced engines and clean fuels technologies.

This project may include the following:

- technical review and assessment of technologies, projects and proposals;
- support for alternative charging solutions and zero emission charging and fueling infrastructure;
- advanced technology curriculum development, mentoring and outreach to local schools;
- emission studies and assessments of near-zero and zero emission alternatives;
- preparation of reports, presentations at conferences for technical and non-technical audiences, meet funding agency/grant requirements and improve public relations by conducting public outreach on successful clean technology demonstration and deployment projects;
- participation in and coordination of workshops and various meetings;
- support for training programs related to fleet operation, maintenance and fueling of alternative fuel vehicles and equipment;
- publication of technical papers as well as reports and bulletins; and
- dissemination of information, including websites development and updates.

These objectives will be achieved by consulting with industry, scientific, health, medical and regulatory experts and co-sponsoring related conferences and organizations, resulting in multiple contracts. In addition, an ongoing outreach campaign will be conducted to encourage decision-makers to voluntarily switch to alternatively fueled vehicles and train operators to purchase, operate and maintain these vehicles/equipment and associated infrastructure.

Potential Air Quality Benefits:

As the Clean Fuels Program transitions increasingly to zero emission vehicle, equipment and infrastructure technologies, there will continue to be challenges in assisting fleets and others to successfully make this transition. The benefits of highlighting challenges, lessons learned, and success stories in the use of zero emission and near-zero emission vehicles, equipment and infrastructure can expedite acceptance and commercialization of these technologies. The emission reduction benefits will contribute to the goals of the 2022 AQMP.

Proposed Project: Support Implementation of Clean Fuels Incentives and Demonstration Projects

Expected South Coast AQMD Cost: $350,000

Expected Total Cost: $400,000

Description of Project:

This project supports implementation of incentive programs, including state and federal grant programs, Carl Moyer, Prop 1B, VW, VIP, CAPP, lower emission school bus, Replace Your Ride, and South Coast AQMD residential EV charger rebate program. Implementation support includes application review, funds allocation, equipment owner reports collection, documentation to CARB, verification of vehicle operation, and other support as needed. Information dissemination is critical to successfully implementing coordinated and comprehensive incentive programs. Outreach will be directed to vehicle OEMs, dealers, individuals and fleets.

Potential Air Quality Benefits:

South Coast AQMD will provide matching funds to implement several key incentive programs to reduce emissions in the Basin. The benefit of highlighting zero emission vehicle, equipment and infrastructure incentives is to expedite acceptance and commercialization of advanced technologies. Future emission reduction benefits will contribute to the goals of the 2022 AQMP. Carl Moyer, Prop 1B, VW, VIP, CAPP, and lower emission school bus incentive programs can reduce large amounts of NOx and PM emissions, and toxic air contaminants in the Basin.

Engine Systems / Technologies

Proposed Project: Develop and Demonstrate Advanced Gaseous- and Liquid-Fueled MD and HD Engines and Vehicle Technologies to Achieve Ultra-Low Emissions

Expected South Coast AQMD Cost: $500,000

Expected Total Cost: $2,000,000

Description of Technology and Application:

The objective of this proposed project would be to support development and certification of near-commercial prototype low emission MD and HD gaseous- and liquid-fueled engine technologies, as well as integration and demonstration of these technologies in on-road vehicles. The NOx emissions target for this project area is 0.02 g/bhp-hr or lower and the PM emissions target is below 0.01 g/bhp-hr. The recent development of low-NOx diesel or NG engine hybrid/plug-in hybrid powertrains have also shown the potential for achieving lower NOx as a combined system. More importantly, the release of EPA HD GHG Phase 3 National Proposed Rulemaking further promoted developed of internal combustion engines using non-carbon containing fuels such as hydrogen. To achieve the lower NOx and PM targets, an effective emissions control strategy must employ advanced fuel system and engine design features such as CDA, aggressive engine calibration and improved thermal management, improved exhaust gas recirculation (EGR) systems, and aftertreatment devices that are optimized using a system approach. This effort is expected to result in several projects, including:

- demonstration of advanced engines in MD and HD vehicles and high horsepower and long haul (HP) applications;
- field demonstrations of advanced technologies in various fleets operating with different classes of vehicles;
- development and demonstration of ultra-low emission renewable fueled hybrid powertrain technology; and
- development and demonstration of optimized engine systems for use with low- and zero carbon alternative fuels such as hydrogen

Anticipated fuels for these projects include but are not limited to alternative fuels (fossil fuel-based and renewable natural gas, propane, hydrogen blends, ethanol, electric and hybrid), conventional and alternative diesel fuels, ultra-low sulfur diesel, renewable diesel, dimethyl ether and gas-to-liquid fuels. There has been significantly more interest as well as a mandate requiring the use of renewable fuels across all sectors due to CARB's Low Carbon Fuel Standard (LCFS). Projects listed under Fuel/Emissions Studies will assess the emissions impact of renewable fuels on past and future optimized combustion technologies. Several key diesel engine development projects that have demonstrated the ability to achieve 0.02 g/bhp-hr NOx under all conditions are near the on-road truck demonstration stage. Truck integration and packaging are another critical step towards commercialization. Prototype trucks are typically placed in revenue service to collect real-world performance data as well as end user feedback for production engines. Furthermore, with the new in-use and low-load emissions requirements within the CARB Omnibus and the U.S. EPA Clean Trucks Plan regulations, we expect these new generation of ultra-low emission engines to comply with the low emissions standard for their full useful life.

In the past two decades, the use of alternative fuel in HD trucking applications has been demonstrated in certain local fleets within the Basin, resulted in wide-spread deployment of NG MD and HD vehicles. These vehicles typically require 200-400 HP engines. Higher HP alternative fuel engines for long-haul applications are beginning to be introduced with Cummins announced the availability of the 15 liter NG engine in MY 2024. However, vehicle range, lack or limited accessible public infrastructure, lack of experience with alternative fuel engine technologies, limited selection of appropriate alternative fuel engine products, and high initial cost are still barriers for more fleets to adopt and deploy larger quantity of alternative fuel vehicles given diminishing incentives for ICEs.

Moreover, as incentive funding shifts away as clean combustion technologies reach full commercial readiness, development of cost-effective technologies that do not rely on incentives are key to drive additional market penetration and emissions reduction. In August 2023, CARB proposed amendments to the already adopted Omnibus Regulation, proposing alignment with the adopted EPA Clean Truck Plan NOx rule in MY2027 and provisions for allowing sale of legacy engines starting MY 2024. South Coast AQMD is closely monitoring low emission ICE availability and ensuring the lowest possible emissions ICEs are being deployed in our region. Due to the slow fleet turn over, the legacy 2010+ diesel fleet will remain in service well into the 2030s and beyond, especially for the high powered applications. Thus, continued development of cost-effective low emission engine technologies is key to reduce the impact of legacy fleets in our region.

Potential Air Quality Benefits:

This project is intended to expedite the commercialization of near-zero emission gaseous- and liquid-fueled MD and HD engine technology both in the Basin and in intrastate operation. The emissions reduction benefits of replacing one 4.0 g/bhp-hr HD engine with a 0.02 g/bhp-hr engine in a vehicle that consumes 10,000 gallons of fuel per year is about 1,400 lb/yr of NOx. MD and HD engines between 6L to 12L using NG and propane achieving NOx emissions of 0.02 g/bhp-hr have been certified and commercialized, with larger displacement and advanced technology (e.g., opposed piston) engines still undergoing development. Further, renewable or blended alternative fuels can also reduce HD engine particulate emissions by over 90 percent compared to current diesel technology. The key to future engine system project success are emissions, cost-effectiveness and availability of future incentives. This project is expected to lead to increased availability of low emission alternative fuel HD engines. Fleets can use the engines and vehicles emerging from this project to comply with South Coast AQMD fleet regulations and towards compliance of the 2022 AQMP control measures as well as future CARB and U.S. EPA low NOx regulations.

Proposed Project: Develop and Demonstrate Low Emission Locomotive Technologies and After Treatment Systems

Expected South Coast AQMD Cost: $200,000

Expected Total Cost: $1,500,000

Description of Technology and Application:

This project aims to support the development and demonstration of gaseous and liquid-fueled locomotive engines. With the upcoming revision of locomotive regulations and the plan to establish Tier 5 or cleaner locomotive emission standards, railroads are exploring the possibility of transitioning from diesel to cleaner fuels or installing aftertreatments to the existing locomotives. The railroad is also considering alternative fuels for its potential economic benefit as compared with diesel fuel. The requirements of locomotive engines as primary generators of electricity to power the locomotive poses serious challenges. From an operational standpoint, there is a significant difference between NG and diesel energy density, a fuel tender would need to provide sufficient fuel for an acceptable range. Locomotives operate at a specific duty cycle different than conventional on-road engines. The engines often run at low speed and have extended periods of idle time. The durability requirements also surpass other forms of transportation.

Large displacement gaseous fueled engines are still in early stages of commercialization in the U.S., especially in the marine sector. The development of engines and systems to fill this need is currently on-going in the locomotive sector. Engine emissions are expected to be below the current 0.2g/bhp-hr NOx standard. Adaptation of alternative fueled locomotives in coordination with required infrastructure improvements by leading manufacturers in the industry, shows great potential for further research and cost savings with fewer maintenance costs and better reliability. Depending on the type of combustion strategy, aftertreatments are likely needed to achieve Tier 4 or cleaner emission standards. Urea-based selective catalytic reduction (SCR) or exhaust gas recirculation (EGR) can be used to reduce NOx emissions and methane slip. Similar low and zero carbon fueled engines could migrate as a retrofit option.

Potential Air Quality Benefits:

The 2022 AQMP identifies the use of low emissions technologies for locomotives where zero emission technologies are not yet commercially available. This project is expected to reduce emissions of around 97 tons per year of NOx per locomotive. The reduction of PM and GHG emissions also show great potential mitigation in environmental justice communities.

Emission Control Technologies

Proposed Project: Develop Methodology and Evaluate and Demonstrate Onboard Sensors for On-Road/Off-Road Vehicles

Expected South Coast AQMD Cost: $250,000

Expected Total Cost: $1,000,000

Description of Technology and Application:

New HD on-road vehicles represent one of the largest categories in the NOx emissions inventory in the Basin. The 2022 AQMP identifies that 83 percent NOx emission reductions from the 2018 level and 67 percent additional reductions beyond already adopted regulations and programs are necessary to meet the 2015 8-hour ozone standard by 2037. Previous in-use emission studies, including studies funded by the South Coast AQMD, have shown significantly higher NOx emissions from on-road HD vehicles than the certification limit under certain in-use operations, such as low power duty cycles. In CARB's adopted HD On-Road "Omnibus" Low NOx regulation, in addition to the lower certification values, there is a low load test cycle and revisions to the not-to-exceed compliance tests. NOx sensor data reporting is also introduced where the vehicle computer is required to store a past period of emissions data to ensure real-world emission reductions are realized over various duty cycles, especially those low power duty cycles in urban areas. An alternative proposed new methodology is to continuously measure real-time emissions from trucks with onboard sensors. Both industry, government and regulators are looking to use sensors to better monitor emissions compliance and leverage the real-time data from sensors to enable advances concepts such as geofencing. CARB's newly adopted HD I/M rules addresses in-use emissions from the older legacy fleets and also has onboard sensors as one of the emission testing methods.

This project category is to investigate near term and long-term benefits from onboard sensors to understand in-use emissions better and reduce emissions from the advanced management concept. The first part of the project is to identify and conduct proof-of-concept demonstrations of feasible candidate technologies, such as:

- laboratory evaluation/verification of new and baseline sensors;
- development and evaluation of next generation sensors;
- development of algorithms to extract sensor information into mass-based metric;
- demonstrate feasibility to monitor emissions compliance using sensors;
- identify low cost option for cost and benefit analysis;
- demonstrate sensors on NG and other mobile sources such as LD, off-highway and commercial harbor craft; and
- development, deployment and demonstration of smart energy/emissions management systems.

Potential Air Quality Benefits:

The proposed research projects will assist the trucking industry to monitor emissions, using sensors as one of the design platform options and identify freight routes which result in lower emissions. Reduction of NOx and PM emissions from mobile sources is imperative for the Basin to achieve NAAQS and protect public health.

Proposed Project: Demonstrate On-Road Technologies in Off-Road and Retrofit Applications

Expected South Coast AQMD Cost: $200,000

Expected Total Cost: $1,000,000

Description of Technology and Application:

On-road HD engines have demonstrated progress in meeting increasingly stringent federal and state requirements. New HD engines have progressed from 2 g/bhp-hr NOx in 2004 to 0.2 g/bhp-hr NOx in 2010, which is an order of magnitude decrease in just six years. Off-road engines, however, have considerably higher emissions limits depending on engine size. For example, Tier 3 standards for HD engines require only 3 g/bhp-hr NOx. There are apparent opportunities to implement cleaner on-road technologies in off-road applications. There is also an opportunity to replace existing engines in both on-road and off-road applications with the cleanest available technology. Current regulations don't usually require repowering (engine replacement) or remanufacturing to meet cleaner emission standards as engines are retired. Unfortunately, this does not take advantage of recently developed clean technologies.

Exhaust gas cleanup strategies, such as EGR, SCR, DPF, electrostatic precipitators, baghouses and scrubbers, have been used successfully for many years on stationary sources. The exhaust from the combustion source is routed to the cleaning technology, which typically requires a large footprint for implementation. This large footprint has made installation of such technologies on some mobile sources prohibitive. However, in cases where the mobile source is required to idle for long periods of time, it may be more effective to route emissions from the mobile source to a stationary device to clean the exhaust stream.

Projects in this category will include utilizing proven clean technologies in novel applications, such as:

- demonstrating certified LNG and CNG on-road engines as well as other clean alternative fuels in off-road applications including yard hostlers, locomotives, commercial harbor craft, gantry cranes, waste haulers and construction equipment;
- implementing lower emission engines requirement in repower applications for both on-road and off-road applications; and
- applying stationary best available control technologies, such as EGR, SCR, scrubbers, DPF, baghouses and electrostatic precipitators, to appropriate on- and off-road applications, such as idling locomotives, commercial harbor craft at dock and HD line-haul trucks at weigh stations.

Potential Air Quality Benefits:

Transfer of mature emission control technologies, such as certified engines and SCR, to the off-road and retrofit sectors offers high potential for immediate emission reductions. Further development and demonstration of these technologies will assist in regulatory efforts which could require such technologies and retrofits.

Appendix A

South Coast AQMD Advisory Groups

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Technology Advancement Advisory Group[1]

Dr. Aaron Katzenstein, Chair	South Coast AQMD
*Sam Wilson	Union of Concerned Scientists
*Jacob Goldberg	Port of Los Angeles
Dr. Bill Robertson	California Air Resources Board
Dr. Michael Kleinman	University of California Irvine
Yuri Freedman	Southern California Gas Company
George Payba	Los Angeles Department of Water and Power
*Dr. Laura Verduzco	Chevron Corporation
Vic La Rosa	Total Transportation Solutions Inc.
Elizabeth John	California Energy Commission
David Pettit	Natural Resources Defense Council
*Dr. Matt Miyasato	FirstElement Fuel
*Morgan Caswell	Port of Long Beach
Rosalie Barinas	Southern California Edison

*Newly appointed member

[1] Members as of February 16, 2024

SB 98 Clean Fuels Advisory Group[2]

Dr. Aaron Katzenstein, Chair	South Coast AQMD
Keith Brandis	Volvo Group
*Brett Stevens	Daimler Truck North America
Dr. John Wall	Independent Consultant in Combustion Technology
Marcus Alexander	Electric Power Research Institute
Dr. Mridul Gautam	West Virginia University, Adjunct Professor, & University of Nevada-Reno
Dr. Wayne Miller	University of California, Riverside, College of Engineering, Center for Environmental Research and Technology
Dr. Petros Ioannou	University of Southern California Director of the Center for Advanced Transportation Technologies
Dr. Scott Samuelsen	University of California, Irvine, Combustion Laboratory/National Fuel Cell Research Center
David Park	Hydrogen Fuel Cell Partnership
*Tom Swenson	Cummins Inc
Ken Kelly	National Renewable Energy Laboratory
Dwight Robinson	Mortimer & Wallace, Inc.

*Newly appointed member

[2] Members as of March 1, 2024

Appendix B

Open Clean Fuels Contracts as of January 1, 2024

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Contract	Contractor	Project Title	Start Term	End Term	South Coast AQMD $	Project Total $
Electric / Hybrid Electric Technologies and Infrastructure						
18232	Hyster-Yale Group Inc	Electric Top-Pick Development, Integration & Demonstration	09/14/18	04/28/25	367,801	3,678,008
18287	Evgo Services LLC	Charging Station and Premises Agreement for Installation of One DCFC at SCAQMD Headquarters	06/27/18	06/26/28	0	0
19166	Phoenix Cars LLC dba Phoenix Motorcars	Battery Electric Shuttle Bus Replacement Project	01/31/19	04/30/24	0	7,311,456
19464	West Basin Container Terminal LLC	Battery Electric Yard Tractor Replacement Project	10/29/20	02/29/24	442,750	3,300,000
20296	Daimler Trucks North America LLC	Deploy Zero Emission Electric Delivery Trucks	05/27/21	03/31/26	0	12,310,000
21153	Volvo Group North America, LLC	Switch-On: Develop and Deploy Seventy Heavy-Duty Battery Electric Vehicles	06/10/21	09/30/24	2,000,000	31,540,000
22036	University of California Riverside	Energy-Efficient Routing for Electric Trucks	09/06/22	04/30/25	99,500	99,500
22120	Los Angeles Cleantech Incubator	Conduct Stakeholder Outreach and ZEV Workforce Plan	03/24/22	03/31/25	95,000	155,000
22177	Daimler Trucks North America LLC	Deploy Class 8 Battery Electric Trucks and Charging Infrastructure	06/16/22	04/30/25	447,638	27,073,593
22247	NFI Interactive Logistics LLC	Deploy Class 8 Battery Electric Trucks, Charging Infrastructure and Distributed Energy Resource Technologies	12/15/22	04/30/25	4,547,126	35,078,329
23072	CALSTART	Charging Related Data Collection, Fleet Analysis and Reporting for Deployment of 100 Commercial Class 8 Battery Electric Trucks	03/08/23	03/31/25	98,582	197,582
Emissions Control Technologies						
23059	University of California Riverside	Study of Emissions and Air Quality Impact from Goods Movement Operations in Southern California Communities	12/27/22	12/26/25	500,000	3,610,000
Engine Systems and Technologies						
18194	CALSTART	Develop and Demonstrate Near-Zero Emission Opposed Piston Engine	05/30/18	12/31/24	2,114,500	17,413,000
20092	Southwest Research Institute	Natural Gas Engine and Vehicles Research and Development - Pent-Roof Medium Duty Natural Gas Engine	10/14/20	04/13/24	475,000	6,000,000
20316	US Hybrid	Natural Gas Engine & Vehicles Research & Development - Plug-In Hybrid CNG Drayage Truck (PHET)	06/02/20	06/02/24	500,000	2,853,006

Contract	Contractor	Project Title	Start Term	End Term	South Coast AQMD $	Project Total $
Fuel / Emission Studies						
21083	University of California Riverside	Assess Emissions Impacts of Hydrogen-Natural Gas fuel Blend on Natural Gas Engines	01/22/22	09/30/2	229,021	583,021
21169	West Virginia University Research Corp	Evaluation of Vehicle Maintenance Costs Between NG and Diesel Fueled On-Road Heavy-Duty Vehicles	09/29/21	03/28/24	100,000	250,000
Fueling Infrastructure and Deployment (NG / RNG)						
18336	ABC Unified School District	FY2017-18 Alternative Fuel School Bus Replacement Program (3 CNG Buses)	10/05/18	11/30/34	117,900	676,500
18337	Alta Loma School District	FY 2017-18 Alternative Fuel School Bus Replacement Program (2 CNG Buses)	10/05/18	11/30/34	78,600	423,000
18344	Bellflower Unified School District	FY 2017-18 Alternative Fuel School Bus Replacement Program (1 CNG Bus)	09/07/18	11/30/34	39,300	225,500
18346	Chaffey Joint Union High School District	FY 2017-18 Alternative Fuel School Bus Replacement Program (6 CNG Buses)	10/05/18	11/30/34	235,800	1,269,000
18348	Cypress School District	FY 2017-18 Alternative Fuel School Bus Replacement Program (1 CNG Bus)	09/07/18	11/30/34	39,300	211,500
18349	Downey Unified School District	FY 2017-18 alternative Fuel School Bus Replacement Program (4 CNG Buses)	09/14/18	11/30/36	157,200	902,000
18350	Fountain Valley School District	FY2017-18 Alternative Fuel School Bus Replacement Program (1 CNG Bus)	09/07/18	11/30/34	39,300	211,500
18351	Fullerton Joint Union High School District	FY2017-18 Alternative Fuel School Bus Replacement Program (4 CNG Buses)	10/05/18	11/30/34	157,200	846,000
18354	Hemet Unified School District	FY2017-18 Alternative Fuel School Bus Replacement Program (5 CNG Buses)	10/05/18	11/30/34	196,500	1,127,500
18355	Huntington Beach Union High School District	FY2017-18 Alternative Fuel School Bus Replacement Program (15 CNG Buses)	10/05/18	11/30/34	589,500	3,382,500
18363	Orange Unified School District	FY 2017-18 Alternative Fuel School Bus Replacement Program (1 CNG Bus)	09/14/18	11/30/34	39,300	225,500
18364	Placentia-Yorba Linda Unified School District	FY2017-18 Alternative Fuel School Bus Replacement Program (6 CNG Buses)	10/05/18	11/30/34	235,800	1,353,000
18365	Pupil Transportation Cooperative	FY 2017-18 Alternative Fuel School Bus Replacement Program (5 CNG Buses)	10/05/18	11/30/34	196,500	1,127,500
18367	Rialto Unified School District	FY 2017-18 Alternative Fuel School Bus Replacement Program (13 CNG Buses)	10/05/18	11/30/34	510,900	2,931,500
18368	Rim Of The World Unified School District	FY2017-18 Alternative Fuel School Bus Replacement Program (3 CNG Buses)	10/05/18	11/30/34	117,900	676,500

Contract	Contractor	Project Title	Start Term	End Term	South Coast AQMD $	Project Total $
Fueling Infrastructure and Deployment (NG / RNG) (cont'd)						
18369	Rowland Unified School District	FY 2017-18 Alternative Fuel School Bus Replacement Program (3 CNG Buses & 1 Propane Bus)	11/02/18	11/30/34	117,900	770,000
18370	San Jacinto Unified School District	FY 2017-18 Alternative Fuel School Bus Replacement Program (2 CNG Buses)	09/14/18	11/30/34	78,600	451,000
18374	Upland Unified School District	FY 2017-18 Alternative Fuel School Bus Replacement Program (4 CNG Buses)	10/12/18	11/30/34	157,200	902,000
20178	Whittier Union High School District	FY 2017-18 Alternative Fuel School Bus Replacement Program	02/21/20	11/30/34	196,500	1,052,500
Hydrogen and Mobile Fuel Cell Technologies and Infrastructure						
15150	Air Products and Chemicals Inc	Install/Upgrade Eight H2 Fueling Stations throughout SCAG (including SCAQMD's HQs H2 station)	10/10/14	04/09/23	762,500	17,097,939
15366	Engineering, Procurement & Construction LLC	Operate and Maitain Publicly Accessible Hydrogen Fueling Station at SCAQMD's Diamond Bar HQs	10/10/14	04/09/22	0	0
15611	Ontario CNG Station Inc	Installation of Ontario Renewable Hydrogen Fueling Station	07/10/15	07/09/22	200,000	2,510,000
17312	Hydrogenics USA Inc	ZECT II - Develop Fuel Cell Range-Extended Drayage Truck	11/20/17	05/30/24	125,995	2,093,146
20033	Port of Long Beach	Sustainable Terminals Accelerating Regional Transportation (START) Phase I	06/04/21	04/30/24	500,000	105,013,765
20038	University of California Irvine	Expansion of the UCI Hydrogen Refueling Station	10/18/19	02/17/27	400,000	1,800,000
21313	Sunline Transit Agency	Deployment of 5 Zero-Emission Fuel Cell Transit Buses	08/27/21	12/31/25	203,706	6,759,910
21386	National Renewable Energy Laboratory	CA Hydrogen Heavy-Duty Infrastructure Research Consortium H2@Scale Initiative	09/03/21	12/31/24	25,000	1,171,000
22082	Frontier Energy Inc	High Flow Bus Fueling Protocol Development	03/3022	08/29/24	25,000	572,500
22084	A-1 Alternative Fuel Systems	Develop and Demonstrate Hydrogen Fuel Cell Medium-Duty Buses	01/19/22	04/18/24	531,166	2,086,608
Stationary Sources - Clean Fuels						
21266	University of California Irvine	Develop Model for Connected Network of Microgrids	08/17/21	02/16/24	290,000	370,000
22262	University of California Irvine	Study of Fuel Cell Microgrids for Backup Power and Transit	06/03/22	06/02/24	370,000	510,000
24035	RockeTruck Inc	Develop and Demonstrate Hydrogen Fuel Cell Mobile Power Generation System	08/20/23	06/30/25	200,000	4,617,067

Contract	Contractor	Project Title	Start Term	End Term	South Coast AQMD $	Project Total $
Technology Assessments and Transfer / Outreach						
09252	JWM Consulting Service	Technical Assistance with Review and Assessment of Advanced Technologies, Heavy-Duty Engines and Conventional and Alternative Fuels	12/20/08	06/30/24	30,000	30,000
12376	University of California Riverside	Technical Assistance with Alternative Fuels, Biofuels, Emissions Testing, and Zero-Emission Transportation Technology	06/01/14	05/31/24	300,000	300,000
15380	ICF Resources LLC	Technical Assistance with Goods Movement, Alternative Fuels and Zero-Emission Transportation Technologies	12/12/14	12/11/24	30,000	30,000
19078	Green Paradigm Consulting Inc	Technical Assistance with Alternative Fuels, Evs, Charging & Infrastructure and Renewable Energy	09/07/18	09/30/24	200,000	871,236
19302	Hydrogen Ventures	Technical Assistance with Hydrogen Infrastructure and Related Projects	04/24/19	04/23/25	50,0000	50,000
20085	CALSTART Inc	Technical Assistance for Development & Demonstration of Infrastructure and Mobile Source Applications	11/08/19	11/07/25	250,000	250,000
20265	Eastern Research Group	Technical Assistance with Heavy-Duty Vehicle Emissions Testing, Analyses & Engine Development & Applications	06/17/20	06/30/24	50,000	50,000
21260	Fred Minassian	Technical Assistance with Incentive and Research and Development Programs	04/13/21	10/12/24	75,000	75,000
22096	AEE Solutions LLC	Technical Assistance with Heavy-Duty Vehicle Emission Testing, Test Methods and Analysis of Real-World Activity Data	11/08/21	11/07/25	100,000	100,000
22273	Green Paradigm Consulting Inc	Technical Assistance with Alternative Fuels, Evs, Charging & Infrastructure and Renewable Energy	04/22/22	04/02/24	200,000	200,000
22274	Gladstein, Neandross & Associates LLC	Technical Assistance with Alternative Fuels & Fueling Infrastructure, Emissions Analysis & On-Road Sources	05/05/22	04/02/24	300,000	300,000
24022	CoMotion Inc	Cosponsor the 2023 CoMotion LA Event	07/12/23	01/31/24	20,000	200,000
24063	CivicWell	Cosponsor the 2023 Clean Mobility Forum	09/28/23	01/31/24	3,000	75,000
24085	Coordinating Research Council Inc	Cosponsor the 34th Real World Emissions Workshop	12/29/23	05/31/24	5,000	85,000

Appendix C

Final Reports for 2023

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South Coast AQMD Contract #14184 **March 2024**

DC Fast Charging Network

Contractor
Green Paradigm Consulting, Inc.

Cosponsors
California Energy Commission
South Coast AQMD

Project Officer
Patricia Kwon

Background
South Coast AQMD received two CEC grant awards for $1.2 million to create a public fast charging network of 50 kW direct current (DC) fast chargers for light-duty vehicles in the South Coast Air Basin. These CEC grants (ARV-12-053 and ARV-13-026) were awarded in 2013 and 2014 at a time when 50 kW chargers had been recently commercialized and there were relatively few chargers installed in public spaces. Originally, there was a planned network of 20 fast chargers to be installed at grocery stores, but the grocery store chain declined to be a site host due to available power and construction impacts. An average of six or more sites were pursued as potential sites before suitable site hosts were identified. This extended the deployment from a 2014 to 2015 timeframe to 2016 to 2018.

South Coast AQMD with its project partners, Green Paradigm Consulting, Inc. (GPCI) and EVgo, installed seven 50 kW DC fast chargers utilizing funds from CEC grant ARV-13-026 and ten 50 kW DC fast chargers utilizing funds from CEC grant ARV-12-053.

At the time of deployment, most EVs utilized 50 kW DC fast chargers, and fast charging was less common than currently. Level 2 charging was still widely utilized in single family homes, but public fast charging and workplace charging were both scarce.

Project Objective
The objectives of this project were to (1) create a network of public fast chargers in the four-county region of South Coast AQMD; (2) supplement available charging; (3) enable electric vehicle (EV) drivers to take longer trips, knowing there is charging en route; and (4) provide DC fast charging for EV drivers in multi-family dwellings who could not easily install chargers at home or did not have access to workplace charging.

Technology Description
GPCI partnered with EVgo to be the installation and network service provider for the fast charging network. EVgo had extensive experience in commercial Level 2 and DC fast charging installations. EVgo released a request for quotes (RFQ) for hardware and ultimately chose BTC Power (BTC) as their hardware provider. The BTC hardware was UL certified and accepted for permitting by multiple cities and counties or authorities having jurisdiction (AHJ). The BTC hardware had dual charging ports and utilized an SAE approved CCS1 charging connector and SAE approved CHAdeMO charging connector. Later, the CHAdeMO connectors were replaced with CCS1 connectors, as these became the predominant charging connector standard for light-duty EVs.

EVgo utilized their own network software to manage charging sessions, handle payment transactions, and monitor charging status. EVgo would remotely diagnose, escalate repairs, and dispatch technicians onsite as needed to maintain uptime and reliability for the charging network.

Status
Although completion of the project took longer than anticipated, all chargers were fully deployed by 2018. These chargers continue to be in service. One of these chargers is at South Coast AQMD headquarters near its front entrance. In 2023, the charger was upgraded to a more recent 50 kW hardware model.

Figure 1. BTC Power 50 kW Fast charger

Results

Seventeen fast chargers were deployed in the South Coast Air Basin. Ultimately fewer sites could be installed given the fixed amount of CEC funding and increased costs for hardware and installation over time.

The La Kretz Innovation Center and Broxton Avenue each had two fast chargers installed. All other sites only had one fast charger installed. Charging sites included:

- City of Calabasas City Hall
- City of Palm Desert City Hall
- Mel's Diner – West Hollywood
- City of Palm Springs Visitor Center
- Moreno Valley Electrical Utility
- City of Temecula Farmers Market
- City of Monterey Park City Hall
- Mel's Diner – Santa Monica
- Victoria Gardens Mall – Rancho Cucamonga
- City of L.A. La Kretz Innovation Center (2)
- LADOT Broxton Avenue Parking – Westwood (2)
- LADOT Little Tokyo/Arts Center Gold Line Station
- LADOT Hollywood & Highland Red Line Station
- South Coast AQMD – Diamond Bar

Total kilowatt-hours and sessions at 10 deployed fast chargers are shown in Table 1.

Table 1. Fast Charging Energy and Session Data

Site	Operational Date	TOTAL kWh	TOTAL Sessions
Mel's Drive in Santa Monica	6/28/18	**1,235**	**85**
Victoria Gardens	6/27/18	**41,802**	**3,360**
La Kretz Innovation Campus	8/28/18	**61,393**	**3,344**
Garage 680 – Westwood	8/28/18	**83,563**	**4,849**
Little Tokyo Gold Line Metro Station	8/3/18	**59,439**	**2,796**
Hollywood & Highland Red Line Metro Station	11/4/18	**21,680**	**1,097**
South Coast AQMD – Diamond Bar	9/28/18	**28,004**	**2,011**

Source: EVgo

Benefits

The South Coast Fast Charging Network provided public charging at a time when public charging was scarce and helped to accelerate commercialization of light-duty EVs.

Project Costs

Total project cost was $1.7 million with $1.2 million funded by two CEC grants and $509,000 in GPCI and EVgo match share.

Commercialization and Applications

Since these chargers were deployed, light-duty EVs and charging technologies have evolved significantly. Light-duty EVs now routinely charge at 15 kW and as much as 350 kW using the CCS1 connector. Battery pack sizes have increased significantly on light-duty EVs with vehicles going from 80- to 100-mile range to as much as 405 miles on a single charge. Innovations on vehicle and charging technology as well as access to high-occupancy vehicle lanes in highly trafficked cities have accelerated the adoption of light-duty EVs, and there is wider consumer choice and acceptance of these technologies. Lessons in the light-duty sector also accelerated the development of medium- and heavy-duty vehicles.

South Coast AQMD Contract #17105 **March 2024**

Zero-Emission Drayage Truck Project

Contractor
BYD Motors, Inc.

Cosponsors
California Air Resources Board
Bay Area AQMD
San Joaquin Valley APCD
San Diego APCD
San Diego Gas & Electric Company
South Coast AQMD

Project Officer
Patricia Kwon

Background
The California Zero Emission Drayage Truck (ZEDT) demonstration project was funded by CARB grant G14-LCTI-09 from the Greenhouse Gas Reduction Fund (GGRF), the South Coast AQMD Clean Fuels Fund, and match share from original equipment manufacturers (OEMs): BYD, Kenworth, Peterbilt, and Volvo. The ZEDT project is part of California Climate Investments (CCI), a statewide initiative that puts billions of Cap and Trade dollars to work to reduce greenhouse gas emissions; strengthen the economy; and improve public health and the environment, particularly in disadvantaged communities.

Project Objective
The GGRF ZEDT project deployed 44 pre-commercial zero- and near-zero emission Class 8 battery electric, compressed natural gas (CNG), and diesel-hybrid electric drayage trucks, as well as supporting infrastructure. These trucks were operated in revenue service through the state of California at the Ports of Los Angeles, Long Beach, San Diego, and Oakland, in the jurisdictions of South Coast AQMD, San Diego APCD, Bay Area AQMD, and San Joaquin Valley APCD.

The GGRF ZEDT project was funded to demonstrate the feasibility of multiple zero- and near-zero emission technology pathways for Class 8 drayage trucks. These technologies included zero-emission battery electric trucks (BETs) as well as near-zero emission CNG-hybrid electric and diesel-hybrid electric trucks. At the time that the GGRF ZEDT project was funded in 2016, it was not known when battery electric trucks would become CARB-certified commercial trucks and whether there would continue to be a need for near-zero technology alternatives such as CNG- and diesel-hybrid electric trucks as interim technologies. The objectives of this project were to (1) demonstrate feasibility of multiple truck technologies, (2) enable lessons learned, and (3) provide more choices for fleet adoption to transition to cleaner truck technologies and meet greenhouse gas (GHG) and criteria pollutant emission reduction goals.

Technology Description
BYD demonstrated and deployed two phases of the BYD Class 8 battery electric truck, which produced the 8TT truck. The 8TT over-the-road tractor, which was still in the design phase at the beginning of the project, was built upon prototypes. Experience in manufacturing Class 2 to Class 5 buses and municipal trucks was utilized.

Phase 1 trucks had a 207 kWh battery pack and utilized 80 kW alternating current (AC) charging with a BYD proprietary connector standard from China. Phase 2 trucks had a larger 435 kWh battery pack and the choice of either 40 kW AC charging with a proprietary connector or 12 kW DC fast charging utilizing the SAE standard CCS1 connector. The use of higher power DC fast charging reduced charging times while enabling higher vehicle range. Phase 1 trucks had a 100-mile range on a single charge and a charging time of three hours. Phase 2 trucks had a 125-mile range and charged in 3.5 hours using 120 kW DC fast charging. The Phase 2 truck utilized a CCS1 connector, which became the industry and SAE-approved standard.

Status
BYD deployed two versions of its 8TT truck. Five Phase 1 trucks were deployed at three fleets: GSC Logistics, TTSI, and AJR Trucking. Twenty Phase 2 trucks were deployed at the same fleets plus six additional fleets: 4Gen Logistics, Golden State

Express, Sea-Logix, Quik Pick Express, Pasha, and Anheuser Busch. These trucks continue to be in revenue service.

Figure 1. BYD Gen 3 8TT Truck Hauling Bud Light to Super Bowl in Los Angeles in 2022

Results

The 25 BYD trucks had a total of 329,429 miles in revenue service by April 2022 and resulted in an estimated annual emissions reduction of 58 metric tons of carbon dioxide equivalent ($MTCO_{2e}$). Fuel efficiency for the BYD trucks is shown in Table 1 below.

Table 1. Project Truck Efficiencies

Vehicle	Minimum Fuel Efficiency (miles/DGE)	Average Fuel Efficiency (miles/DGE)	Maximum Fuel Efficiency (miles/DGE)
TransPower Battery Electric	12.20	16.69	21.10
BYD Battery Electric Phase I	12.80	12.80	12.80
BYD Battery Electric Phase II	9.70	13.13	17.70
Kenworth Series Hybrid with CNG Range Extender	4.29	4.70	5.10
Volvo Parallel Plug-In Hybrid	7.50	7.50	7.50
Baseline Diesel	4.35	4.82	5.60
Baseline CNG	5.30	5.30	5.30

Near the end of the ZEDT project, participating fleets were surveyed and interviewed on the truck and infrastructure deployment process and lessons learned. Eighteen of the 22 fleets in the project indicated advanced technology drayage trucks should be 1:1 replacements for conventional diesel drayage trucks in their fleets with the following key improvements:

- Total cost of ownership must be competitive with conventional drayage trucks.
- Increase vehicle range so that trucks could be assigned to all routes operated by drayage companies. Minimum vehicle range of 150 miles, with some fleets suggesting 200 miles to 350 miles.
- Reliability should be similar to conventional drayage trucks which typically do not exceed 10% out of service.
- Service and maintenance and parts availability should be comparable to conventional trucks, with fleets preferring to perform most maintenance at their in-house facilities.
- Ensure vehicle certifications are in place prior to deployment.
- Reduce charging time to 90 minutes or less.
- Make Capital costs similar to diesel trucks.
- Assist in obtaining full insurance coverage for advanced technology trucks.
- Tractor weights should be similar to diesel trucks.
- Improve tractor safety.
- Implement standardization of charging hardware.
- Create viable options to reduce electricity costs while allowing opportunity charging.
- Manufacture reliable vehicles and provide good technical support.
- Facilitate better coordination between fleets, OEMs, and utilities to better understand vehicle and infrastructure technologies to reduce costs, maintenance and repair options, safety requirements and vehicle features.
- Improve training programs for fleet operators, managers, drivers, maintenance technicians, and first responders.

Benefits

BETs were able to prove themselves from a commercial standpoint and are currently the main zero-emission truck technology available. BYD deployed commercial versions of their Class 8 BETs from the development and demonstration work in the ZEDT project. Between Phase 1 and Phase 2 versions of their trucks, they increased battery size and switched to DC fast charging with CCS 1 connectors to increase vehicle range.

Project Costs

Total project cost for the BYD trucks was $9.5 million with $6.2 million provided by CARB, $2.3 million by South Coast AQMD, and $990,000 in BYD match share.

Commercialization and Applications

In the time since the ZEDT project started in 2016, Class 8 BETs have become CARB certified and commercialized from many OEMs, including BYD, Peterbilt, Volvo, Kenworth, and Daimler. The ZEDT project enabled four OEMs to work towards developing, demonstrating, and deploying Class 8 trucks on multiple fuel platforms, at a time when the future zero- and near-zero emission pathways for these trucks were not known.

South Coast AQMD Contract #17207 **April 2022**

Advanced Technology Drayage Truck Demonstration Project Transportation Power / Peterbilt Motors

Contractor

Peterbilt Motors
Transportation Power, LLC (TransPower)

Cosponsors

California Air Resources Board
Bay Area AQMD
San Joaquin Valley APCD
San Diego APCD
San Diego Gas & Electric Company
South Coast AQMD

Project Officer

Seungbum Ha

Background

Heavy-duty diesel trucks contribute disproportionately to diesel particulate matter (DPM) and nitrous oxide (NOx) emissions throughout the South Coast Air Basin. DPM and NOx contribute to morbidity of various conditions and impact communities along goods movement corridors. Removing harmful DPM, NOx, and carbon dioxide (CO_2) serves to attack health and environmental issues associated with fossil fuel internal combustion engines.

Project Objective

Peterbilt Motors completed 12 Class 8 battery electric trucks through partnership with TransPower. All 12 trucks participated in real-world technology demonstrations with fleets in the Bay Area, South Coast, and San Diego regions.

Technology Description

Project trucks demonstrated an ability to operate at a gross combined weight rating of 80,000 lbs. The drive system used dual electric motors rated at 300 kW. Electric drive and energy storage systems used a dual-acting onboard inverter-charger unit (ICU) to apply and restore energy used to power the trucks. The ICU inverted the facility grid alternating current (AC) to direct current (DC) on board the trucks for storage in the energy storage system (ESS). Originally planned high-density lithium-iron-phosphate (LFP) batteries were changed in design to a second chemistry of nickel-manganese-cobalt (NMC). Changing to NMC provided project trucks with more power density than previously planned LFP batteries. ESS was of modular design with each module rated at 440 V and 44 kWh. Trucks carried six to eight modules each, with ESS size from 264 to 352 kWh. Electric Vehicle Service Equipment (EVSE) was rated at 70 kW.

Project trucks used onboard energy to drive electric motors. Automated manual transmission (AMT) takes the force generated and passes it through a driveline and differential to turn the wheels. Traditional trucks use the internal combustion process consuming fossil fuels to achieve the same work as project trucks.

The difference between project trucks and traditional trucks comes from zero-tailpipe emissions. Project trucks sequester tailpipe emissions by using electricity to accomplish traditional truck work. The elimination of tailpipe emissions while accomplishing traditional truck work is the key advancement demonstrated during project.

Status

The project was completed April 2022, and the Final Report is on file with complete technical details of the project.

Development of project trucks consisted of design and integration of component assemblies into a single unit, with testing and demonstration. Selection of appropriate Peterbilt vehicle model and design for fit of TransPower's proprietary electric vehicle kit (eKit) were the key first steps. Peterbilt selected Model 579 and Transpower designed an eKit as a direct-fit solution to the 579-rolling chassis. TransPower manufactured the Model 579 eKit including ESS, using established and newly developed processes at their

Escondido, CA facilities. Hardware to build project trucks was delivered to TransPower for integration into complete trucks from 2016 to 2018. Software for project trucks was built during the same period at TransPower facilities.

Pre-deployment testing of project trucks consisted of tests used to validate traditional Peterbilt trucks at the PACCAR Technology Center. Deployment period tested the reliability and durability of the complete electric truck.

Total mileage accumulation for project trucks was 132,828 miles, with six trucks accumulating 100,000 miles. There were several key challenges to mileage accumulation: (1) difficulties in installing EVSE limited use of several trucks, (2) resistance to interacting with high-voltage systems from fleet operators and maintenance technicians caused extended downtimes and repair times, (3) TransPower's limited expert field service team was expected to repair all issues. As a result, several fleets lost confidence in the truck and opted to not use project trucks. Expert repairs, software, and hardware upgrades provided support for accumulation of end of project mileage.

Project 579 electric vehicle (579EV) was tested at the famous Pikes Peak Colorado Springs Road Course Climb. Figure 1 displays the 579EV used to climb Pikes Peak in Colorado. The video of the 579EV's climb can be found online at: https://www.peterbilt.com/about/news-events/news-releases/peterbilt-model-579EV-conquers-pikes-peak

Figure 1. 579EV Climbing Pikes Peak

Results

TransPower-powered 579EVs resulted in an estimated annual emissions reduction of 74.5 metric tons of carbon dioxide equivalent ($MTCO_{2e}$). Third-party analysts identified Transpower-powered Peterbilt 579EVs as the most fuel-efficient trucks demonstrated during project for average and maximum fuel efficiency. Results shown in Table 1.

Table 1. Project Truck Efficiencies

Vehicle	Minimum Fuel Efficiency (miles/DGE)	Average Fuel Efficiency (miles/DGE)	Maximum Fuel Efficiency (miles/DGE)
TransPower Battery Electric	12.20	16.69	21.10
BYD Battery Electric Phase I	12.80	12.80	12.80
BYD Battery Electric Phase II	9.70	13.13	17.70
Kenworth Series Hybrid with CNG Range Extender	4.29	4.70	5.10
Volvo Parallel Plug-In Hybrid	7.50	7.50	7.50
Baseline Diesel	4.35	4.82	5.60
Baseline CNG	5.30	5.30	5.30

TransPower and Peterbilt's battery electric trucks were able to perform drayage service. Expected range limitations and component durability are the predominate project issues.

Benefits

Battery electric Class 8 drayage trucks provide a significantly more fuel-efficient vehicle option to the drayage industry along with public health benefits. Operating electric drayage trucks eliminated tailpipe emissions sequestering DPM, NOx, and CO_2 at the vehicle source during the project. Deploying electric drayage trucks at scale positively impacts communities along cargo routes while lowering business operating cost through increased fuel efficiency.

Project Costs

Peterbilt and TransPower received $8 million to build and deploy project trucks with the bulk of funds for design and build. In-kind match from both Peterbilt and TransPower equaled over $3 million.

Commercialization and Applications

Peterbilt and TransPower entered a commercial agreement to bring a publicly available battery electric vehicle to market in March 2022. TransPower was acquired by Meritor Inc. and received a grant to deploy battery electric refuse trucks with the City of Los Angeles. The refuse truck fleet for the City of Los Angeles consists of 700 Class 8 refuse trucks using liquified petroleum as fuel. With successful project outcomes, there is the potential to completely replace the city's fleet with battery electric refuse trucks.

South Coast AQMD Contract #18129 **June 2023**

Versatile Auxiliary Power (VAP) System Field Integration Demonstration Results

Contractor

Electric Power Research Institute

Cosponsors

Southern California Edison
Los Angeles Department of Water and Power

Project Officer

Lisa Mirisola, Maryam Hajbabaei

Background

Stationary operations conducted by utility, telecommunications, and public service works either utilize gasoline or diesel auxiliary power units (APU) to provide electricity for tools or vehicle internal combustion engine (ICE) driven power takeoffs (PTO) for hydraulic tool support. While both APU and ICE applications provide added utility to service vehicles, they contribute to the environment with harmful emissions, noise, and excessive costs associated with maintenance of ICE-driven APU and PTO-equipped vehicles. The operation of these tools is vital to business operations, and therefore the reliability of operation is crucial regardless of fuel consumption and emissions concerns. With tightening restrictions on emissions issued at a statewide level, the compromise impacts the usage characteristics, functionality, and output of APU- and ICE-driven systems, further constraining business operations.

Project Objective

The Versatile Auxiliary Power (VAP) system is a modular, advanced chemistry battery energy storage system developed in conjunction with the Electric Power Research Institute (EPRI), South Coast AQMD, Southern California Edison (SCE), Los Angeles Department of Water and Power (LADWP), and hardware manufacturers Envoltz, and FreeWire.

Technology Description

The VAP system is a standalone unit designed to deliver emissions and noise-free alternating current (AC) power for auxiliary tool use or opportunity charging for electric vehicles (EV). The VAP system consists of a lithium-based energy storage system that provides high-voltage direct current (DC) energy to an internal AC inverter system. The VAP system provides 120/208 volts alternating current (VAC) power to support plug-in accessories and tools, while also providing 12 volts of direct current (VDC) power to support chassis loads, including lights or cabin accessories when it is mounted on or connected to a vehicle. The VAP system is intended to support a full eight-hour workday and replenish the battery energy during the off-time via J1772 EV charging station.

Status

A total of three VAP systems were acquired and evaluated in laboratory and/or field evaluation. The first unit, developed by Envoltz, LLC, consisted of a 6.6 kWh lithium battery pack. The second "MOBI-GEN" unit was developed by FreeWire, using a 40 kWh battery, capable of 8 kW of power delivery. A third "MOBI-EV" unit also from FreeWire, consisted of an 80 kWh battery system, delivering up to 11 kW of continuous power. The MOBI-GEN unit was designed as a trailer-mounted unit, capable of being towed by any service vehicle, while the MOBI-EV was a self-contained enclosure designed to be located within parking lots to provide opportunity charge to parked EVs.

Figure 1. VAP System by Envoltz, LLC

Figure 2. VAP System by FreeWire (MOBI-GEN)

Figure 3. VAP System by FreeWire (MOBI-EV)

Results

During the initial validation of the Envoltz unit, the hardware experienced an issue with inconsistent energy capacity output due to internal hardware issues with the inverter system. During laboratory evaluation, the inverter caused the Envoltz VAP system to truncate output to a 40% state of charge (SOC), rather than its designed 10% SOC. Due to this issue, the hardware was sent back to the manufacturer for repairs.

The MOBI-GEN unit arrived at the SCE laboratory for further evaluations. During initial functionality validations, the system was observed to have inconsistent operation due to internal hardware damage. It was revealed that the damage may have been caused while the unit was transported. The MOBI-GEN was sent back a second time for repairs. Once the unit was fully functioning, additional testing was performed, further developing performance issues around the software control and 24 VDC power delivery, which impacted system controls and displays. Once the MOBI-GEN unit was repaired, discharge tests were performed on the unit by charging an EV, electric scooter, or a resistive load bank from July 2019 to March 2020, prior to testing suspension due to COVID-19. The SOC usage over time is shown in Figure 4.

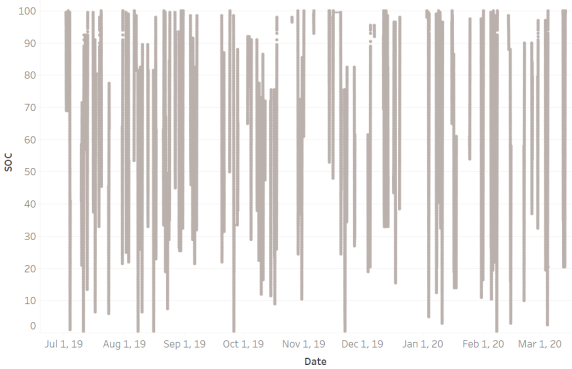


Figure 4. VAP System MOBI-GEN SOC Over Time

The final MOBI-EV unit was deployed into a parking lot environment for use to charge e-mobility units, including scooters and vehicles. Preliminary calculations have shown the MOBI-EV unit to have powered up to 200,000+ miles of electric scooter transportation during its demonstration from September 2019 to February 2020. A summary of the MOBI-EV performance during that duration is shown in Table 1.

Table 1. VAP System MOBI-EV Usage Summary

Month / Value	Sept 2019	Oct 2019	Nov 2019	Dec 2019	Jan 2020	Feb 2020	Total Average
Average Daily Power (kW)	1.57	1.60	1.83	1.68	1.64	5.47	2.30
Average Daily Energy Consumption (kWh)	2.78	4.48	5.58	4.80	4.82	6.07	4.75
Average Daily Usage (hr)	13.5	15.13	1.89	16.71	12.30	1.43	10.17

Benefits

Despite initial technical hurdles, the VAP systems have proven to be an effective means to distribute consistent power for auxiliary applications. During the deployment of the MOBI-EV unit, the performance was shown to charge scooters and parked cars without the time and cost consuming infrastructure updates. Previous iterations of VAP systems have also shown benefit in off-highway use, providing a means of emissions and fuel consumption reductions while retaining AC power output.

Project Costs

South Coast AQMD contributed $105,000 to the project, which was part of a $273,000 total cost for the Phase 2 demonstration. Additional cost sharing also included funding from SCE for $128,000, LADWP for $20,000, and EPRI for $20,000.

Commercialization and Applications

As the cost per kilowatt-hour of battery storage lessens, the VAP system will prove itself to be a candidate worthy to compete with current ICE-based APU systems. The scalability and consistency of lithium performance in APU applications will increase marketability and further assist with commercialization to prove that lithium battery usage is worthy to operate in markets outside of EVs.

South Coast AQMD Contract #20097 **March 2024**

Operate, Maintain and Network EV Chargers

Contractor
Greenlots/Shell Recharge Solutions

Cosponsors
South Coast AQMD

Project Officer
Patricia Kwon

Background
In 2017, ninety-two (92) Level 2 electric vehicle (EV) charging ports were installed at South Coast AQMD headquarters to provide workplace and public charging. Chargers were installed in several areas of the parking lot, including under the solar carport, the upper parking deck, front lobby entrance, and behind Conference Room CC8. As part of this installation, the Level 2 chargers utilized Greenlots networking software for payment processing and data collection. In 2019, Greenlots was acquired by Shell and began doing business as Shell Recharge Solutions.

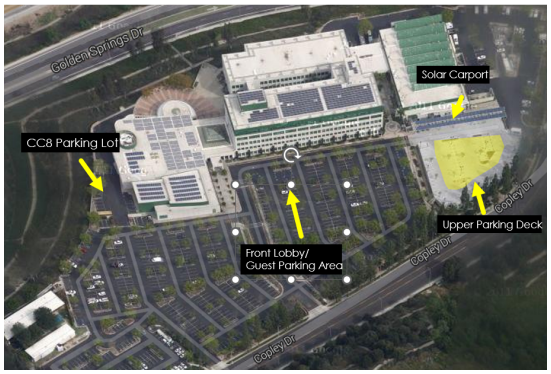


Figure 1. Map of Level 2 EV Charging Locations at South Coast AQMD Headquarters

Project Objective
Greenlots/Shell Recharge Solutions has been providing payment processing and data collection of EV charging data to calculate Low Carbon Fuel Standard (LCFS) credits from these EV chargers. In addition, Greenlots/Shell Recharge Solutions has been performing routine maintenance and replacement of parts and minor repairs since the chargers were installed in 2017. The initial maintenance contract was renewed to continue providing payment processing, data collection, and maintenance services until 2023.

Technology Description
Since the EV chargers were installed in 2017, additional networking software and maintenance companies have been established to provide services to increase uptime on workplace and public charging sites. When the chargers were initially installed, networking software providers such as Greenlots/ Shell Recharge Solutions had to integrate their software with hardware manufacturers. BTC Power, Inc., the manufacturer of the Level 2 chargers at South Coast AQMD, integrated with the Greenlots software in 2016 to provide a convenient user interface for EV drivers. At the time, many hardware and networking software providers had proprietary systems which did not allow other companies to integrate with their hardware. To avoid the issue of having hardware with proprietary software, Open Charge Point Protocols (OCPP) and other open standards such as Open Automated Demand Response (ADR) Protocols and Standards were developed and agreed upon by the industry. The intent was to avoid stranded assets when hardware or networking software providers went out of business, leaving other companies unable to continue operating these charging assets.

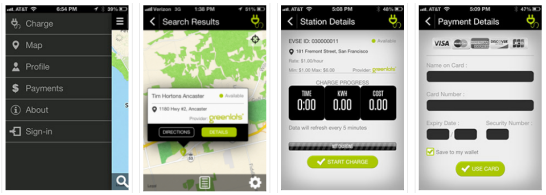


Figure 2. Networking software features included payment by phone app or radio frequency identification (RFID) card, text/email notifications for charging events, and automatic escalation of repairs.

Status

The EV chargers have operated beyond their 3-year warranty and expected equipment lifetime. Staff is exploring the ability to utilize revenue from the sale of LCFS credits to fund the replacement of hardware. A request for proposal (RFP) or request for quote (RFQ) procurement process will be utilized to identify suitable vendors of hardware and networking software as well as uptime maintenance services to maintain the chargers for 3 to 5 years post-installation.

Figure 3. Level 2 EV Chargers Under the Solar Carport in the Upper Parking Lot Near the Employee Entrance

Results

Since the chargers were deployed in 2017, the EV chargers have been used extensively with over 76,885 charging sessions and 847,446 kWh dispensed. Charging decreased significantly starting in March 2020 when the office was closed to the public due to the pandemic. Staffing at the office continues to be at reduced levels with most staff coming to the office once per week.

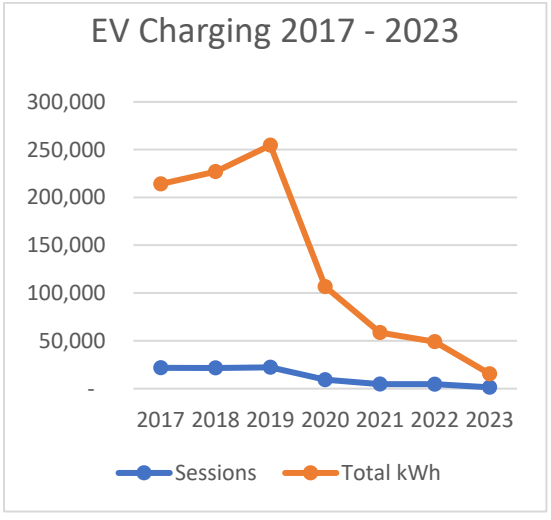


Figure 4. Energy Utilization, Duration and Number of Charging Sessions from January 2017 to March 2023

Figure 5. Number of Charging Sessions, Energy Used (kWh), and Duration by Time of Day from May 2019 to May 2020

Benefits

Installation of the 92 Level 2 EV charging ports at South Coast AQMD enabled staff and visitors to travel in zero-emission mode and extend their available electric range. Prior to 2020, light-duty battery electric vehicles (BEVs) had a limited range of 100 to 120 miles and required charging during the day to facilitate the return commute.

Project Costs

Greenlots/Shell Recharge Solutions networking software and maintenance was provided under a 3-year contract at $155,000. This provided routine maintenance and minor repairs, with some parts replaced at additional cost when they were outside the warranty period.

Commercialization and Applications

Workplace and public charging for Level 2 chargers have become increasingly available in the greater Los Angeles metropolitan region, enabling wider spread use of BEVs for commuting and leisure. BEVs now commonly have an electric range of 200 to 250 miles or more. Level 2 public charging has been replaced largely by 150 kW direct current fast charging, which allows BEVs with significantly larger battery sizes to minimize the amount of dwell time needed for opportunity charging.

South Coast AQMD Contract #21077 **March 2023**

Customer Experience (CX) of Zero-Emission Trucks and Mobile Electric Vehicle (EV) Infrastructure Project

Contractor

Daimler Trucks North America (DTNA) LLC (prime)
Gladstein, Neandross & Associates (sub)

Cosponsors

South Coast AQMD
Bay Area AQMD
Southern California Edison
Pacific Gas & Electric

Project Officer

Phil Barroca, Sam Cao, Fan Xu

Background

With funding from the South Coast AQMD, DTNA developed petroleum-free, zero-emission battery electric trucks that provided immediate NOx and greenhouse gas (GHG) emission reductions. These reductions supported the South Coast AQMD in achieving its alternative fuel use, petroleum displacement, and criteria pollutant reduction goals. This project demonstrated real emission reductions by deploying new zero-emission, on-road, medium-duty and heavy-duty (M&HD) truck technology with supporting infrastructure that replaced M&HD diesel trucks in real-world fleet operations, including port drayage and local delivery.

Project Objective

The objective of this project was to design, develop, deliver, and demonstrate six Class 8 eCascadia and two Class 6 eM2 electric trucks focused on shorter terms demonstrations with more fleets. Partnering with some of the largest trucking companies in North America, the battery electric trucks (BETs) were scheduled to be delivered to a select group of 12 to 18 DTNA customers for short-term, real-world demonstrations lasting between 2 to 9 months, between Q2 2020 to Q2 2022. Participating fleet operators included high-profile and large fleet companies, such as Amazon, JB Hunt, Schneider, Ryder, Kroger (Ralphs), Knight-Swift, HUB Group, and several others.

This project built upon the already successful launch of the South Coast AQMD-supported DTNA Innovation Fleet project, where DTNA partnered with Penske Truck Leasing and NFI to deliver 20 prototype Class 6 and Class 8 BETs in in the South Coast Air Basin. While the Innovation Fleet project had many benefits – not the least of which was the development of the first large OEM-produced zero-emission electric trucks – ultimately, only two heavy-duty fleet operators gained experience with BETs. Thus, via this CX Fleet project, DTNA expanded access and experience with zero-emission BETs to a much larger number of its heavy-duty customers, all of whom represent some of the largest and highest profile fleet operators in North America. All these customers are also part of the DTNA "EV Council," which was assembled in 2018, shortly after the South Coast AQMD approved the first grant for Innovation Fleet.

Figure 1. Project Freightliner eCascadia and eM2

Technology Description

The Class 8 eCascadia and Class 6 eM2 were designed to be integrated into a range of freight duty cycles to obtain varied operational data for drayage, delivery, and logistics operations, supported by a comprehensive network of high-powered 150kW rated charging infrastructure throughout the South Coast Air Basin. The vehicle specification targets for both the eCascadia and the eM2 are detailed in the table below.

Model	GVWR	Horse power	Axle Configuration	Battery Capacity	Connector Type
eCascadia	80,000 lbs.	455 hp	6x4	400-600 kWh	CCS-1
eM2	26,000 lbs.	220 hp	4x2	225-300 kWh	CCS-1

Status

The project demonstration was completed on June 18, 2022.

Results

Vehicle Development: Despite initial production delays associated with global supply chain issues and

the COVID-19 pandemic, all project deliverables were achieved, including all major vehicle specification targets for vehicle range, horsepower, and efficiency. The vehicles developed under this project utilized lessons learned from the Innovation Fleet deployment. In turn, feedback from the CX Fleet deployment informed the series production versions of both the eM2 and the eCascadia.

CX Fleet Program Demonstration: The pilot demonstration was very successful, generating key data on vehicle efficiency, charging capabilities, and operational costs to inform technology advancement and the business case for MHD zero-emission vehicles. CX Fleet trucks were able to be deployed to a larger number of fleets than required under the contract, providing for lessons learned. These additional fleets were also unique deployments, allowing for the BETs to be driven on routes distributing food and beverage, last mile delivery, and freight, among others.

The table below summarizes results related to total vehicle miles traveled (VMT) and vehicle efficiency.

Fleet	Truck	Total Miles	Average Miles/Day	Average kWh/Mile
J.B Hunt	ZZ0191 (eM2)	4,797.00	389.99	5.06
Ryder	ZZ0201 (eM2)	2,312.91	139.77	2.81
J.B Hunt	ZZ0234 (eCas)	10,575.01	810.26	17.85
Knight Swift	ZZ0208 (eCas)	4,259.07	545.34	15.48
Kroger	ZZ0232 (eCas)	8,009.26	370.30	7.79
SCE	ZZ0232 (eCas)	2,416.65	381.00	7.42
Schneider	ZZ0233 (eCas)	14,586.27	895.96	14.41
May Trucking	ZZ0233 (eCas)	369.15	52.72	2.02
HUB	ZZ0234 (eCas)	17,068.23	918.21	13.31
Estes	ZZ0200 (eM2)	1,614.78	177.35	5.93
Amazon	ZZ0232 (eCas)	1,218.47	189.42	6.80
Ryder	ZZ0230 (eCas)	9,220.49	503.11	10.00
Reyes Holdings	ZZ0233 (eCas)	4,077.23	278.36	11.04
Ruan	ZZ0234 (eCas)	110.11	110.11	1.78
Harbor Distributing	ZZ0233 (eCas)	2,846.73	187.22	7.82
DHE	ZZ0200 (eM2)	250.40	50.08	1.65
TTSI	ZZ0232 (eCas)	620.88	103.48	5.06

Benefits

Emissions Reductions: Despite COVID-19 stay-at-home orders and global supply chain issues that impacted this project, total avoided emissions over the 84,353 combined fleet miles traveled during the demonstration period resulted in significant emissions reductions in the South Coast Air Basin.

Project Costs

The grant funding for this project was provided by South Coast AQMD. DTNA and their fleet customers provided the remaining cash and in-kind cost-share for this work.

	Total Budget
DTNA	$4,919,500
Bay Area AQMD	$322,500
SCE / PG&E	$500,000
South Coast AQMD	$1,000,000
TOTAL	**$6,742,000**

Commercialization and Applications

Building off the lessons learned of the Innovation Fleet project, the CX Fleet project tested the eM2 and eCascadia in many more real-world environments, and incorporated BETs into the operations of a diverse group of fleets. For most fleets, this was their first exposure to the technology and served as a critical milestone on their transition to zero-emission vehicles.

The project was built upon the critical model first developed in Innovation Fleet, of utilizing M&HD electric vehicle supply equipment (EVSE) infrastructure deployment to understand challenges and best practices to remove barriers to adoption and accelerate the market for zero-emission technologies.

This approach to commercialization is key to achieving the increased range, overall performance, and cost-savings to accommodate regional haul routes of up to 220 miles per day, covering a wider array of use cases and making up 70% of freight routes in the United States.

South Coast AQMD Contract #19439 **January 2024**

High-Efficiency, Ultra-Low Emissions, Heavy-Duty Natural Gas Engine Research and Development

Contractor

Cummins, Inc.

Cosponsors

Department of Energy
California Energy Commission
South Coast AQMD

Project Officer

Sam Cao

Background

Natural Gas (NG) is an abundant resource across the United States. New discoveries and extraction methods have led to a dramatic rise in shale gas development, making the United States the world's leading NG producer while changing the dynamics of the global energy mix. Advances in the ability to capture methane for the production of Renewable Natural Gas (RNG) have added a robust renewable alternative to conventional fuels. Due to recent low carbon fuel and renewable fuel initiatives, RNG is well positioned to further increase the interest in and motivation for expanding the use of natural gas in the transportation sector. Expanding the use of NG can have an impact on the overall economic stability of California and improve consumer choice, as well as reduce local, regional, and global air pollution.

Inherently, all NG engines benefit from a favorable hydrogen-to-carbon ratio of the fuel molecule and relatively lower fuel cost per unit energy compared to diesel or other liquid petroleum fuels. However, their lower engine thermal efficiencies compared to diesel engines reduce the advantages in greenhouse gases (GHG) and total cost of ownership for most heavy-duty vehicle applications, making the adoption of NG vehicles challenging. Adoption of NG vehicles is also increasingly challenged by the technology advances in electrification and reductions in battery costs. Hence, improvements in spark-ignited (SI) natural gas engine efficiencies and base engine costs reductions are necessary to further the penetration of NG in heavy-duty applications. This project aims to drive simultaneous improvements in fuel efficiency and cost while achieving ultra-low emissions.

Project Objective

The main objectives of the project are to reach an improvement in efficiency similar to conventionally fueled vehicles and to reduce emissions to near-zero levels. Key goals of the project are:

- Develop an NG-specific combustion system design that is built upon a proven high cylinder, pressure-capable, heavy-duty base engine platform in the 12 to 15L displacement range.
- Demonstrate cycle average brake thermal efficiency (BTE) 38-40%.
- Demonstrate peak BTE 41-43%.
- Maintain 0.02 g/brake bhp-hr NOx capability.
- Demonstrate a diesel-like torque curve rating of 450-500bhp and 2100-2500 Newton meter (Nm) peak torque.
- Develop an engine integrated on a global platform to enable up to 20% system cost reduction.
- Confirm readiness for a technology readiness level (TRL) of 6 demonstration with a prototype system.

Technology Description

Several public-private cooperative programs have been executed in the past to improve SI engine fuel economy. Hence, the roadmap for how to improve fuel economy of stoichiometric engines is reasonably well understood for mid-bore engines at 0.02g nitrous oxide (NOx)/bhp-hr tailpipe emissions. This project aims to demonstrate the scalability of these learnings to drive simultaneous improvements in fuel efficiency and cost while achieving ultra-low NOx.

Engine technologies like those used in the diesel SuperTruck and SuperTruck II programs are considered, but with design and optimization being driven exclusively for the SI stoichiometric engine topology. Engine changes have entitlement capability in combustion cycle efficiency, in air handling management, and in optimized parasitic

and frictional losses. These engine technologies alone are expected to improve powertrain efficiency beyond 10%. In addition, alignment of global common base engine designs for volume and scale drives advantages in lower costs of the powertrain.

Status

The project was completed 2 months in advance of the schedule. All deliverables were marked complete on June 30, 2023, with set targets achieved. Final report with technical details has been submitted.

Results

This project resulted in the first purpose-designed heavy-duty NG engine being compared to previous diesel engine-based NG designs that achieved improved efficiency while maintaining ultra-low NOx emission levels with diesel-like performance and reduced costs. The engine met the project objectives by:

- Demonstrating 42% peak BTE against the requirement of 41-43% or 11% fuel consumption improvement over current ISX12N product.
- Demonstrating 40.2% steady-state certification cycle average BTE. That is 13% fuel consumption improvement over current ISX12N product.
- Demonstrating capability to meet current product heavy-duty NG-level emissions, including low NOx 0.02 g/hp-hr.
- Demonstrating diesel-like torque curve capability of 2500Nm@1000rpm and 512hp@1800rpm.
- Estimating up to 31% engine system cost reduction over current product ISX12N against requirement of 20%, utilizing reduced cost aftertreatment system.

There is a profound and direct interaction between engine efficiency, capability, and power density demands. Improvements in SI natural gas engine technology and hardware designs, such as those demonstrated in this project, allow for more aggressive tuning (higher compression ratio, combustion phasing, and brake thermal efficiency) and/or increased power output with similar boundary conditions and limits imposed. Fundamentally, the tumble-based combustion system and balanced port designs allow for efficiency enhancement and higher power output, though knock limited behavior remains a challenge for higher Brake Mean Effective Pressure (BMEP). Additional modeling refinement based on the experimental results captured here may be considered to help uncover additional enablers. Continued investigation and opportunities demand additional resources and funding beyond those currently allocated.

Benefits

A 15L NG engine with improved efficiency, ultra-low emissions, and similar performance to that of a diesel engine enables opportunities for a broader NG adoption in the market with improved total cost of ownership and payback periods for the vehicle fleets. Adoption rates are also benefited with a share in the heavy-duty line-haul applications which to date has been a challenge for the smaller ISX12N engine. Cummins' internal analysis forecasts an increase in North America NG heavy-duty market share by 2030. Renewable natural gas availability, usage, and infrastructure developments are critical factors contributing to increased adoption rates. Cummins plans to utilize the technology learnings from this project into its future product launches in 2027+ and make the key learnings gained from this project available to the public through several technology transfer activities, such as conference presentations, consortium presentations, and technical papers. Government emissions regulators will be able to use the results to confirm that next generation natural gas engines can deliver a lower CO_2 solution required for future GHG standards while still maintaining the capability to achieve near-zero NOx emissions.

Project Costs

Below are the total budget and costs for the project:

	Budgeted	Actual Spent
NGV Consortium (DOE, CEC, South Coast AQMD)	$4M	$4M
Cummins	$6.669M	$12.98M
Total Project Cost	**$10.996M**	**$16.98M**

Commercialization and Applications

Cummins has plans in place to launch a big bore 15L NG engine in 2024 with a similar technology as today's ISX12N. Technology demonstrated in this project will go through a development cycle with tentative plans for a 2027 launch.

South Coast AQMD Contract #20199 **October 2023**

Develop Natural Gas and Propane Conversion Systems for Medium-Duty Vehicles

Contractor
Hexagon Agility

Cosponsors
South Coast AQMD
Southern California Gas Company

Project Officer
Sam Cao

Background
The new Ford 7.3L V8 engine has been released with a gaseous fuel prep option for medium-duty chassis. This engine replaces the widely used 6.8L V10, which Agility previously certified to meet the CARB optional 0.02 g/bhp-hr NOx standard and which they sold to fleet customers. The new 7.3L engine fuel system will be used by target compressed natural gas (CNG) and liquified petroleum gas (LPG) fleet vehicles for many years.

Project Objective
The objectives of this project were (1) to develop hardware and software necessary to operate and certify the next generation Ford 7.3L engine on both CNG and LPG. The engine will be able to operate on renewable natural gas (RNG) and renewable propane as well, as available. (2) Apply best available regulator, injector, and fuel control technology to this engine. For natural gas, the injection method will be gaseous and for propane the injection method will be liquid propane. (3) Perform in-vehicle testing for drivability as well as dyno testing to ensure emissions. (4) Conduct certified emissions tests and obtain EPA Certificate of Conformity (CoC) and CARB executive order (EO) at a certified NOx level of 0.02 g/bhp-hr. An additional future objective will be to examine the feasibility of achieving NOx levels of 0.01 g/bhp-hr. Durability tests will also be conducted to ensure there is no reduction in reliability.

Technology Description
Agility brings a unique approach to emissions control technology, focusing on stability of fuel control and consistency of delivery to each cylinder and, if necessary, refining the balance of catalyst precious metal loading.

Agility's unique advantage is precision optimization of all aspects of engine and vehicle performance, while operating on alternative fuels. Agility's fuel system components integrate seamlessly with the original equipment manufacturer (OEM) engine control module, and the proprietary calibration enables Agility to achieve the most stringent emissions certification standards while maintaining performance that is indiscernible from petroleum.

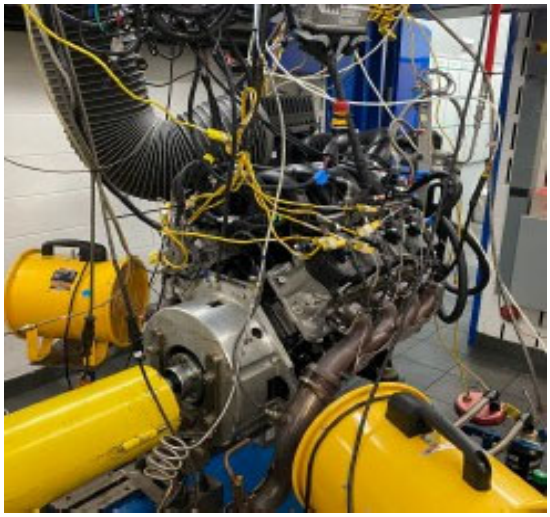


Figure 1: A 7.3L Engine Installed and Instrumented at the Test Dyno Facility in Detroit, MI

Status
Agility has completed all objectives and has received the EPA CoC and CARB EO for the 7.3L engine running on CNG and LPG. Both fuels are certified at a NOx level of 0.02 g/bhp-hr. The project objectives were completed, and the certification documents were received on December 23, 2022. The final report for the project

has been submitted and is on file for additional technical details.

Results

Agility was able to achieve the primary project objective of 0.02 g/bhp-hr NOx on the stock OEM exhaust system. In pursuit of the additional future objective of 0.01 g/bhp-hr NOx, the team worked to further refine the calibration.

After hundreds of dyno tests, the team was able to achieve a weighted composite score of 0.003 g/bhp-hr NOx for CNG and 0.007 g/bhp-hr for LPG, running the standard Federal Test Procedure (FTP) for heavy-duty transient cycle regulatory testing. This result was achieved without any modification to the stock OEM exhaust system.

Additional in-vehicle calibration development confirmed the drivability of the engine on CNG and LPG is equal to or better than the original gasoline fuel. The test vehicle was driven in a wide variety of conditions and environments with testing to confirm engine response, shifting, starting, and general drivability.

	CO	CO2	NOX	NMHC
Agility 7.3L CNG	3.00	505	0.003	0.04
OEM Gasoline	5.90	619	0.06	0.11
CA Standard	14.4	623	0.20	0.14
Agility % of Standard	21%	81%	2%	29%

Figure 2: Certified Emissions Summary for the 7.3L Running CNG. Actual NOx Test Level was 0.003 g/bhp-hr

To ensure engine longevity had not been compromised, Agility conducted substantial durability testing on each engine configuration. A test protocol was established in partnership with Mahle Powertrain Engineering using the OEM limits for alternative fuels as the applicable standard. Tests included peak cylinder pressure, exhaust manifold and valve temp, engine coolant temp, exhaust temp, catalyst temp, cylinder pressures, oil and piston temps. Agility designed a specialized engine instrumentation package and test battery to compare the test engine to the OEM's published limits for temperatures and pressures. The results of durability testing demonstrate that Agility's modifications do not cause the 7.3L engine to exceed any of the OEM's established durability limits or not to exceed thresholds.

Benefits

This project resulted in two near-zero NOx engine configurations being certified by EPA and CARB. Further, it has been demonstrated that a NOx level of 0.01 g/bhp-hr is possible for a port-injected engine of this size.

Project Costs

The total project cost was $1,834,000, with cost share from South Coast AQMD and SoCalGas of $453,500 and $154,325, respectively. Note that the SoCalGas cost share applies only to the CNG portion of the project. Agility contributed the remainder of the project cost.

Commercialization and Applications

Agility's CNG and LPG certifications cover any vehicle with the 7.3L over 14,000 lbs gross vehicle weight rating (GVWR). These include Ford Super-Duty Pickup Trucks (F250, F350, F450), Ford Super-Duty Chassis and Box Trucks (F550, F650, F750) and the Ford F59 Strip-Chassis.

These vehicles are used in a wide variety of vocations including final mile delivery, airport shuttles, utility trucks, linen services, food services, among others.

Conversations are ongoing with customers and fleet owners to determine commercialization requirements and to balance pricing against ongoing certification maintenance costs.

South Coast AQMD Contract #21103 **January 2024**

Investigate Effects of Ethanol-Gasoline Fuel Blend on Criteria Emissions and Secondary Organic Aerosol (SOA) Formation from Light-Duty Vehicles

Contractor
University of California Riverside/College of Engineering-Center for Environmental Research & Technology

Cosponsors
Growth Energy
CARB
South Coast AQMD
Renewable Fuels Association

Project Officer
Sam Cao

Background

In May 2019, the United States Environmental Protection Agency (U.S. EPA) approved the use of gasoline blended with up to 15% ethanol by volume (E15) for year-round use to help regulated parties comply with the Federal Renewable Fuels Standard (RFS) and California's Low Carbon Fuels Standard (LCFS). Higher levels of ethanol in gasoline would also reduce petroleum reliance and has the potential to reduce greenhouse gas (GHG) and criteria pollutant emissions from refineries. Currently, gasoline in California contains up to 10% ethanol by volume (E10). The 2016 Air Quality Management Plan (AQMP) estimated gasoline contributes to over 45% of total energy consumed in the South Coast Air Basin (Basin). Additionally, the emissions inventory reflects that light-duty gasoline vehicles are the fourth highest category in all of NOx emissions and the second highest category in all Volatile Organic Compounds (VOC) emissions. Previous work has shown the potential for emission reductions with higher ethanol blends, but results are inconsistent with lower ethanol blends such as E15.

Project Objective

California Air Resources Board (CARB), Renewable Fuels Association, Growth Energy, National Corn Growers Association, and the United States Council for Automotive Research (USCAR) came together to co-fund one of the largest emissions studies on light-duty vehicles. The objective of this project was to conduct emissions testing on twenty 2016 and newer modern gasoline-fueled vehicles over triplicate Federal Test Procedure (FTP) cycles. The E10 fuel was a California Reformulated Gasoline. The summer-grade E10 fuel was sourced from four different refineries selected by CARB. The E10 fuels were blended in four equal parts to create the final E10 fuel. The E15 fuel was created by splash blending denatured ASTM D4806 fuel grade ethanol with the final E10 fuel. Testing was performed on vehicles with different technologies, including gasoline direct injection (GDI), port fuel injection (PFI) as well as PFI+GDI fuel systems that are representative of the current California gasoline fleet. One hybrid electric vehicle (HEV) equipped with a PFI engine was also used. The vehicle test matrix had provisions for five vehicles on each emissions standards category (i.e., SULEV30, ULEV50, ULEV70, and ULEV125).

South Coast AQMD supplemented the initial funding to investigate the secondary organic aerosol (SOA) formation potential from a subset of vehicles operated on both E10 and E15 fuels.

Technology Description

For these experiments, diluted exhaust from all vehicle/fuel combinations was introduced into a 30 m3, 2 mil fluorinated ethylene propylene Teflon film Mobile Atmospheric Chamber (MACh). A fraction of the tailpipe exhaust emissions was directly injected from the CVS system through two Ejector Diluters (Air-Vac TD11OH) in parallel into the MACh, which was already half-filled with purified air. The vehicle exhaust was captured over the entire duration of the FTP cycle. Prior to each experiment, the MACh was flushed with clean air for at least 24 hours to ensure the levels of the particles and gases were below detection limits (H2O < -50°C dew point; NOx, CO, NMHC, and O3 at ~0 ppb; and PM= 0 µg m-3). Total experiment dilution ranged between 150:1 to 200:1, which is similar to the dilution of tailpipe emissions in ambient atmosphere. Variations in the dilution rate are due to reactor integrity. By nature of the reactor design, pressure inside is always positive regardless of

integrity, thereby preventing contamination from ambient air. Once max volume was achieved, the UV lighting array was turned on and the enclosure was sealed. 80µ of H2O2 was injected via syringe pump over an 8-hour time period starting at the beginning of the experiment to act as an additional hydroxyl radical source and to enhance the chemistry in the reactor.

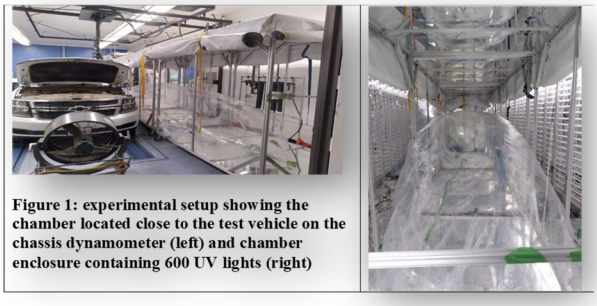


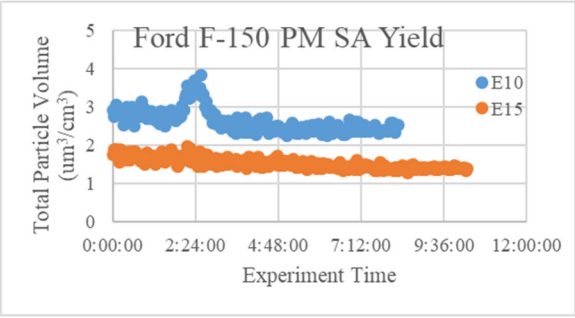
Figure 1: experimental setup showing the chamber located close to the test vehicle on the chassis dynamometer (left) and chamber enclosure containing 600 UV lights (right)

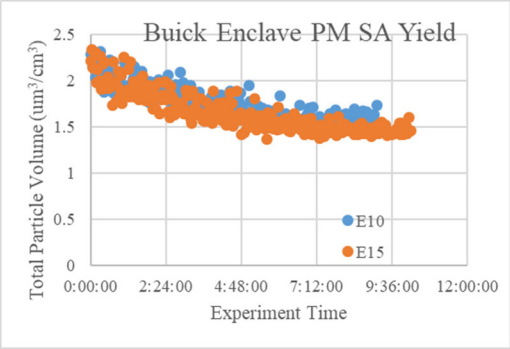
Status

The project test was completed largely in 2022, and final reporting was completed in 2023.

Results

The results from the photooxidation experiments have been abbreviated due to the very low total secondary aerosol yield. This is the first time we experienced this phenomenon. Previous studies funded by South Coast AQMD on older technology vehicles showed appreciable amounts of SOA formation. Here, we show results from two vehicles, namely the Ford F-150 and the Buick Enclave, which were selected to be representative of the results obtained from all vehicles tested for this campaign. Figure 2 below shows the total PM volume in the chamber as a function of photooxidation time. Time zero signifies the beginning of the photooxidation in the chamber. For both vehicle/fuel combinations, there was a decrease in total PM on the order of ~10%.





Benefits

To achieve national ambient air quality standards and protect public health, one of South Cost AQMD's primary priorities is to reduce NOx and PM emissions from mobile sources, while realizing GHG co-benefits where possible. The proposed E15 fuel study will help to better understand the air quality and public health impact of the new fuel formulation on light-duty vehicles, which are significant contributors to the emissions in the Basin.

Project Costs

The grant funding for this project was provided by South Coast AQMD. CARB and RFA/Growth Energy provided the remaining cash and in-kind cost-share for this work.

Project Partner	Cost-Share
CARB	$500,000
GFA/Growth Energy	$600,000
South Coast AQMD	$200,000
Total Project Cost	**$1,300,000**

Commercialization and Applications

The introduction of a new gasoline blend will likely have important implications in the air quality of the South Coast Air Basin. Thus, understanding the fuel effect on tailpipe emissions and secondary aerosols from gasoline vehicles is an important step in understanding air quality in our region. Previous works have shown emissions reduction potential with higher ethanol blends, but there has been inconsistency with lower ethanol blends. In a 2019 CARB-published Staff Concept Paper, there were concerns raised on potential higher NOx emissions from E15 using model-based predictions.

South Coast AQMD Contract #19313 **April 2023**

H2Freight Heavy-Duty Hydrogen Vehicle Fueling Station

Contractor
Equilon Enterprises LLC, dba Shell Oil Products US ("Shell")

Cosponsors
South Coast AQMD
California Energy Commission
Toyota Motor North America

Project Officer
Maryam Hajbabaei

Background
Equilon Enterprises LLC (dba Shell Oil Products US) designed, engineered, permitted, constructed, and made operational a hydrogen refueling station at 2140 Pier B Street, Long Beach, California 90813. This station is located at the Port of Long Beach and serves heavy-duty freight vehicles and other types of hydrogen fuel cell electric vehicles. The station consists of a fenced equipment compound that encloses hydrogen storage, compression, and cooling equipment. The fueling area has two 700 bar and one 350 bar dispensers and two point of sale terminals.

Project Objective
The objective of this project was to open one of the first three public access heavy-duty vehicle fueling stations for hydrogen fuel cell electric trucks (FCET).

The project developed a high-capacity hydrogen fueling station, servicing and promoting the expansion of zero-emission fuel cell electric trucks at one of the world's largest freight hubs at the Port of Long Beach (POLB). With a station designed to source hydrogen from 100% renewable biogas, the infrastructure was installed strategically to make the greatest impact on the available heavy-duty fleet. The station uses either delivered gaseous hydrogen or produced gaseous hydrogen piped from the neighboring third-party tri-generation fuel cell power generation plant operated by Fuel Cell Energy (FCE).

Shell selected Fiedler Group as engineer of record; Fueling and Service Technologies, Inc. (Fastech) as general contractor; and Nel Hydrogen as equipment vendor, commissioning engineer, and operations and maintenance contractor.

Technology Description
The hydrogen station has a refueling capacity of 1,500 kg per day. The station has two, single-hosed 700 bar dispensers on one fueling island and one single-hosed 350 bar dispenser on a second fueling island.

The heavy-duty hydrogen station also feeds a light-duty hydrogen refueling station for private use by Toyota Logistics Services to complete pre-delivery hydrogen fills of production Toyota Mirai Fuel-Cell Electric Vehicles that are off-loaded from marine vessels at the port facility. This is prior to road transport distribution to dealerships for delivery to public customers. The light-duty station has one, single-hosed 700 bar dispenser on one fueling island.

Status
The station was deemed operational as of July 1, 2021. The mandatory one-year operational period for data collection was from August 1, 2021 to July 31, 2022, with the station continuing to remain open beyond this period. Incremental engineering improvements were made while the station was open, and subsequently the station successfully passed a four-truck, back-to-back fueling Station Acceptance Test on September 28, 2022.

The hydrogen supply will continue to be delivered until the neighboring third-party tri-generation fuel cell power generation plant comes online and begins to produce hydrogen. At the time of this report, startup of the third-party tri-generation facility was expected in 2023.

Figure 1. Aerial View of Site, November 2022

Results

If one average Class 8 hydrogen FCET takes one average Class 8 diesel heavy-duty truck off the road, the amount of diesel displaced due to this station operation would be approximately 7,895 gallons of diesel, based on the 4,155 kg of hydrogen dispensed to Class 8 hydrogen FCETs during the data collection period.

From the one year of operational data, 92,000 kg of carbon dioxide equivalent (CO2e) were avoided. Further emission savings (negative) are presented in the following table.

Emission Type	Savings (kg)
Nitrogen oxides (NOx)	-28.8
Particulate matter of size less than 2.5 microns ($PM_{2.5}$)	-0.6
Hydrocarbons (HC)	-1.4
Carbon monoxide (CO)	-10.1

In April 2022, Shell established a Low Carbon Fuel Standard Tier 2 joint fuel pathway that utilizes dairy and swine manure (DSM) renewable natural gas via "book and claim" accounting. The pathway is consistent with the Lookup Table Compressed Hydrogen pathway produced in California from central steam methane reforming of biomethane with two notable exceptions: (1) the gaseous hydrogen transportation distance is lower than the default 100 miles distribution distance modeled in the Lookup Table pathway carbon intensity (CI), and (2) the feedstock for hydrogen production was matched to biomethane attributes derived from DSM digester gas with a lifecycle CI of -147.2 gCO2e/MJ.

Across the first year of operation, the Long Beach heavy-duty freight vehicle hydrogen fueling station dispensed 51% renewable content, and 49% non-renewable content. This calculation is based on the 100% renewable hydrogen pathway established in April 2022, in the middle of the data collection period. During the first year of operation, the weighted average CI of the hydrogen fuel dispensed was -15.44 grams of CO2e per megajoule of hydrogen dispensed. The negative value connotes a greenhouse gas emission savings.

Benefits

The project has demonstrated station performance via station testing and retail fueling and has proven to be both safe and reliable. From the creation of the Tier 2 joint pathway, the station has dispensed 100% renewable hydrogen, and the sustainable economic business model is exemplified.

Shell will continue to operate and maintain the hydrogen refueling station to support Toyota, as well as the committed fleet operators who intend to operate the FCETs beyond the term of the funding agreement and through the end of the economic lifetimes of the trucks and station equipment.

The station has and will continue to support further demand growth with successful deployment of FCETs with capability to fuel trucks at 350 bar and 700 bar and expand access to multiple truck operators.

Figure 2. Port of Long Beach Station Filling Fuel Cell Electric Trucks

Project Costs

South Coast AQMD contributed $1,200,000 to this project. Under its Grant Funding Opportunity GFO-17-603, the California Energy Commission funded an additional $8,000,000. The balance of funds was paid by Shell and Toyota for a total budgeted station cost of $12,001,800.

Commercialization and Applications

With the economic operation demonstrated through this project and as demand grows for zero-emission technologies in the Port of Los Angeles and the Port of Long Beach, refueling for FCETs will need to expand to a network of refueling stations positioned along drayage and warehouse routes. Having completed the heavy-duty hydrogen refueling station at the Port of Long Beach, Shell is positioned to continue servicing the increasing demand with multiple heavy-duty hydrogen refueling stations in the area that could become part of such a future network.

Shell aims to build on the successes of the heavy-duty hydrogen refueling station at the Port of Long Beach and envisions a California-wide heavy-duty Hydrogen Refueling Network. Similar to the station at the Port of Long Beach, the primary use-case for the network will be for Class 8 and other medium/heavy-duty trucks, including drayage, medium-, and long-haul with intense duty cycles and return-to-base operations.

Appendix D

Technology Status

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Technology Status

For each of the core technologies discussed in this report, numerous factors influence the proposed allocation of funds, ranging from overall Environment & Health Benefits, Technology Maturity and Compatibility, and Cost, summarized in the technology status table. Within the broad factors above, sub-factors for each type of project may be considered, as summarized below:

Environment and Health Benefits

Criteria Pollutant Emission Reduction potential continues to receive the highest priority for projects that facilitate NOx reduction goals outlined in the 2022 AQMP. Technologies that provide co-benefits of GHG and Petroleum Reduction are also weighted favorably, considering the Clean Fuels Program leverages funds available through several state and federal programs, as well as overall health benefits in reducing exposure to Ozone and PM2.5, especially in disadvantaged communities.

Technology Maturity & Compatibility

Numerous approaches are used to evaluate technology maturity and risk given the potential uncertainty in real world operations. This approach can include numerous weighting factors based on the assessed importance of a particular technology. Key metrics considered include Infrastructure Constructability, which evaluates the potential of fuel or energy for the technology and readiness of associated infrastructure, and Technology Readiness, which includes research and development of the technology and large scale deployments that consider ability for near-term implementation and operational compatibility for end users. These combined factors can provide an assessment for market readiness of the technology.

Cost/Incentives

The long-term costs and performance of advanced technologies are highly uncertain, considering continued development of these technologies is likely to involve unforeseen changes in basic design and materials. Additionally, economic sustainability – or market driven – implementation of these technologies is another key factor for technology research, development, demonstration and deployment projects. To accelerate the demonstration and deployment, especially of pre-commercialization technologies, local, state and federal incentive programs are crucial, but may be underfunded to enable large scale deployments.

Staff has developed an approach to evaluating core technologies, especially some of the specific platforms and technologies discussed in the draft plan and annual report. The technology status evaluation below utilizes experience with implementing the Clean Fuels Program for numerous years, as well as understanding the current development and deployment of the technologies and associated infrastructure, and are based on the following measurement:

● Excellent ◓ Good ◯ Satisfactory ◒ Poor • Unacceptable

The table below summarizes staff evaluation of the potential projects anticipated in the Plan Update, and technology developers, suppliers and other experts may differ in their approach to ranking these projects. For example, staff ranks Electric/Hybrid Technologies as Excellent or Good for Criteria Pollutant and GHG/Petroleum Reduction, but Satisfactory to Excellent for Technology Readiness, Satisfactory to Excellent for Compatibility, and Satisfactory to Poor for Costs and Incentives to affect large scale deployment. It is further noted that the Clean Fuels Fund's primary focus remains on-road vehicles and fuels, and funds for off-road and stationary sources are limited.

This approach has been reviewed with the Clean Fuels and Technology Advancement Advisory Groups, as well as the Governing Board.

Technologies & Proposed Solutions	Environment & Health			Technology Maturity & Compatibility				Cost	
	Emissions Reduction	GHG/Petroleum Reduction	Health Benefits	Infrastructure Constructability	Technology Readiness	Near-Term Implementation/ Duty Cycle Fulfillment Capability	Operations Compatibility	Relative Cost & Economic Sustainability	Incentives Available
Electric/Hybrid Technologies									
Plug-In Hybrid Heavy-Duty Trucks with Zero-Emission Range	◓	○	◓	●	○	●	●	◒	●
Heavy-Duty Zero-Emission Trucks	●	◓	●	◓	◓	◓	○	●	◓
Medium-Duty Zero-Emission Trucks	◓	◓	●	◓	◓	◓	◓	●	◓
Medium- and Heavy-Duty Zero-Emission Buses	●	◓	●	◓	◓	◓	○	●	◓
Light-Duty Zero-Emission Vehicles	●	◓	●	●	●	●	●	●	◓
Plug-In Hybrid Light-Duty Vehicles with Zero-Emission Range	◓	○	◓	●	●	●	●	●	◓
Hydrogen & Fuel Cell Technologies									
Heavy-Duty Trucks	●	◓	◓	○	◓	○	◒	●	◓
Heavy-Duty Buses	●	◓	◓	○	●	◓	◓	●	◓
Off-Road – Locomotive/Marine	●	◓	◓	○	○	◒	◒	●	●
Light-Duty Vehicles	●	◓	◓	○	◓	○	○	◒	◓
Zero Emission Infrastructure									
Light-Duty Electric Charging Infrastructure	-	-	-	●	●	●	●	●	●
Medium- and Heavy-Duty Electric Charging Infrastructure	-	-	-	◓	◓	◓	◓	◒	◓
Light-Duty Hydrogen Fueling Infrastructure	-	-	-	○	●	●	●	◒	◓
Medium- and Heavy-Duty Hydrogen Fueling Infrastructure	-	-	-	○	◓	◓	◓	◒	◓
Infrastructure – Production, Dispensing, Certification	-	-	-	○	○	◒	◒	●	◒
Engine Systems									
Ultra-Low NOx Medium- and Heavy-Duty Renewable Diesel Vehicles	◓	◓	○	●	◓	●	●	◓	●
Renewable Gaseous and Alternative Fuel Ultra-Low NOx Medium- and Heavy-Duty Vehicles	◓	◓	○	●	●	●	●	◓	●
Ultra-Low Emission Off-Road Applications	◓	◓	○	◓	◓	◓	●	◓	○
Stationary Clean Fuel Technologies									
Low-Emission Stationary & Control Technologies	◓	◓	◓	◓	○	○	◓	○	◒
Renewable Fuels for Stationary Technologies	○	●	◓	◓	○	○	○	○	◒
Vehicle-to-Grid or Vehicle-to-Building/Storage	●	●	◓	○	○	◒	○	◒	◒
Emission Control Technologies									
Alternative/Renewable Liquid Fuels	○	◓	◓	◓	●	●	●	◓	○
Advanced Aftertreatment Technologies	◓	○	◓	○	◓	◓	●	○	◒

● Excellent ◓ Good ○ Satisfactory ◒ Poor ● Unacceptable

Appendix E

List of Acronyms

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LIST OF ACRONYMS

3B-MAW—3-bin moving average windows
A-1—A-1 Alternative Fuel Systems
AB—Assembly Bill
AC—absorption chiller
ACS—alternative charging solution
ACF—Advanced Clean Fleets Regulation
ACFR—Annual Comprehensive Financial Report
ACT—advanced clean transportation / American Clean Truck regulation
ADA—American with Disabilities Act
AER—all-electric range
AFRC—air/fuel ratio control
AFVs—alternative fuel vehicles
AGL—Academy of Global Logistics
ALPR—automated license plate recognition
APCD—Air Pollution Control District
AQMD—Air Quality Management District
AQMP—Air Quality Management Plan
ARB—Air Resources Board
ARM—advanced RISC machine
ARRA—American Recovery & Reinvestment Act
AWMA—Air & Waste Management Association
BACT—best available control technology
BATS—blended aftertreatment system
BEB—battery electric bus
BESS— battery energy storage system
BET—battery electric tractor / battery electric truck
BEV—battery electric vehicle
BMEP—brake mean effective pressure
BMS—battery management system
BSNOx—brake specific NOx
BTC—Broadband Telecom Power, Inc.
BTE—brake thermal efficiency
CAE— computer aided engineering
CAMFC—Commercial Advancement of Mobile Fuel Cells
CAN—controller area networks
CAP—Clean Air Protection
CAAP—Clean Air Action Plan
CaFCP—California Fuel Cell Partnership
CAPP— Community Air Protection Program
CARB—California Air Resources Board
CATI—Clean Air Technology Initiative
CBD—Central Business District (cycle) - a Dyno test cycle for buses
CCE—closed cycle efficiency
CCF—California Clean Fuels
CCHP—combined cooling, heat and power
CCI—California Climate Investments
CCV—closed crankcase ventilation
CDA—cylinder deactivation
CDFA/DMS—California Department of Food &Agriculture/Division of Measurement Standards
CE—construction equipment
CEC—California Energy Commission
CE-CERT—College of Engineering – Center for Environmental Research and Technology
CEMS—continuous emission monitoring system
CERP—Community Emission Reduction Plan
CEQA—The California Environmental Quality Act
CFD—computational fluid dynamic
CFR—Code of Federal Regulations
CHBC—California Hydrogen Business Council
CHE—cargo handling equipment
C-ITS—connected intelligent transportation system
CMAQ—community multi-scale air quality
CNG—compressed natural gas
CNGVP—California Natural Gas Vehicle Partnership
CO_2—carbon dioxide
CO—carbon monoxide
COG—council of governments
ComZEV—Commercial Zero-Emission Vehicle
CPA—Certified Public Accountant
C-PORT—Commercialization of POLB Off-Road Technology
CPUC—California Public Utilities Commission
CRADA—Cooperative Research and Development Agreement
CRDS—cavity ring-down spectroscopy
CRP—Charge Ready Program
CRT—Charge Ready Transport / continuously regenerating technology
CSC—city suburban cycle
CTE—Center for Transportation and the Environment
CTF—Clean Truck Fund
CVAG—Coachella Valley Association of Governments
CWI—Cummins Westport, Inc.
CX—Customer Experience
CX Fleet Project—Customer Experience of Zero Emission Trucks and Mobile Electric Vehicle Infrastructure Project
CY—calendar year
DAC—disadvantaged community
DC—direct connection / direct current
DCFC—direct connection fast charger
DCM—dichloromethane
DEF—diesel exhaust fluid
DEG—diesel equivalent gallons
DER—distributed energy resource
DERA—Diesel Emissions Reduction Act

LIST OF ACRONYMS (cont'd)

DGE—diesel gallon equivalents
DF—deterioration factor
DHE—Dependable Highway Express
DME—dimethyl ether
DMS—Division of Measurement Standards
DMV—Department of Motor Vehicles
DOC—diesel oxidation catalysts
DOE—Department of Energy
DOT—Department of Transportation
DPF—diesel particulate filters
D-PMag—dual permanent magnet motor
DPT3—Local Drayage Port Truck (cycle) - where 3=local (whereas 2=near-dock, etc.)
DRC—Desert Resource Center
DRI—Desert Research Institute
DT—delivery truck
DTNA—Daimler Trucks North America LLC
EATS—emissions aftertreatment system
ECM—emission control monitoring / engine control module
EDD—electric drayage demonstration
EDTA—Electric Drive Transportation Association
EERE—Energy Efficiency and Renewable Energy
EGR—exhaust gas recirculation
EIA—Energy Information Administration
EIN—Energy Independence Now
EMFAC—Emission FACtors
EPRI—Electric Power Research Institute
E-rEV—extended-range electric vehicles
ESD—emergency shut down
ESS—energy storage system
EV—electric vehicle
EVITP—electric vehicle infrastructure training program
EVSE—electric vehicle supply equipment
FCEB—fuel cell electric bus
FCET—fuel cell electric truck
FCEBCC—Fuel Cell Electric Bus Commercialization Consortium
FCEV—fuel cell electric vehicle
FCTO—Fuel Cell Technologies Office
FCV—fuel cell vehicle
FCXRDT—fuel cell extended range delivery truck
FS—feasibility study
FTA—Federal Transit Administration
FTP—federal test procedures
FY—fiscal year
G2V—grid-to-vehicle
g/bhp-hr—grams per brake horsepower hour
GC/MS—gas chromatography/mass spectrometry
GCW—gross combination weight
GCVW—gross container vehicle weight
GDI—gasoline direct injection
GGE—gasoline gallon equivalents
GGRF—Greenhouse Gas Reduction Relief Fund
GH2—green hydrogen
GHG—greenhouse gas
GM—goods movement
GNA—Gladstein, Neandross & Associates, LLC
GNSS—global navigation satellite system
Go-Biz—Governor's Office of Business and Economic Development
GPCI—Green Paradigm Consulting, Inc.
GPS—global positioning system
GPU—gas processing unit
GREET—Greenhouse Gasses, Regulated Emissions and Energy Use in Transportation
GTI—Gas Technology Institute
GTL—gas to liquid
GVW—gross vehicle weight
GVWR—gross vehicle weight rating
H2—hydrogen
H2NIP—Hydrogen Network Investment Plan
H&SC—California Health and Safety Code
HCCI—Homogeneous Charge Combustion Ignition
HCD—hydrogen contaminant detector
HCHO—formaldehyde
HCNG—hydrogen-compressed natural gas (blend)
HD—heavy duty
HDD—heavy-duty diesel
HDDT—highway dynamometer driving schedule
HD-FTP—Heavy-Duty Federal Test Procedure
HD I/M—heavy-duty inspection and maintenance
HD-OBD—heavy-duty on-board diagnostics
HDV—heavy-duty vehicle
HEV— hybrid electric vehicle
HEVI-LOAD—heavy-duty electric vehicle infrastructure load, operations and deployment
HHDDT—heavy heavy-duty diesel truck schedule
HMI—Human Machine Interface
HPLC—high-performance liquid chromatography
HRSC—heat recovery steam cycle
HT—high throughput
HTFCs—high-temperature fuel cells
HTPH—high throughput pretreatment and enzymatic hydrolysis
HV—high voltage
HVIP— Hybrid and Zero-Emission Trucks and Bus Voucher Program
HyPPO—Hydrogen Progress, Priorities and Opportunities report
Hz—Hertz
IBT—Intermodal Bridge Transport
ICE—internal combustion engine
ICEPAG—International Colloquium on Environmentally Preferred Advanced Generation
ICEV—internal combustion engine vehicle

LIST OF ACRONYMS (cont'd)

ICT—Innovative Clean Transit Regulation
ICU—inverter-charger unit
ICTC—Interstate Clean Transportation Corridor
ISX12N—11.9-liter NZE engine
ITS—intelligent transportation system
IVOC—intermediate volatility organic compound
JETSI—Joint Electric Truck Scaling Initiative
kg—kilogram
kW—kilowatt
kWh—kilowatt-hour
L—liter
L9N—8.9-liter natural gas engine
LADOT—City of Los Angeles Dept. of Transportation
LADWP—Los Angeles Department of Water and Power
LAEDC—Los Angeles Economic Development Corporation
LA Metro—Los Angeles County Metropolitan Transportation Authority
LAX—Los Angeles Airport
LBCT—Long Beach Container Terminal
LC—lane change
LCA—life cycle assessment
LCFS—Low Carbon Fuel Standard
LD—light-duty
LED—low emission diesel
LFP—lithium iron phosphate
Li—lithium ion
LIGHTS—Low Impact Green Heavy Transport Solutions
LIMS—Laboratory Information Management System
LLC—low load cycle
LLNL—Lawrence Livermore National Laboratory
LNG—liquefied natural gas
LO-SCR—light-off selective catalytic reduction
LPG—liquefied petroleum gas or propane
LRUSA—Landi Renzo USA Corporation
LSM—linear synchronous motor
LSV—low-speed vehicle
LUV—local-use vehicle
LVP—low vapor pressure
M&HD— medium- and heavy-duty
MATES—Multiple Air Toxics Exposure Study
MC—mass compensated
MCE—multi cylinder engine
MCS—megawatt charging standard
MCFC—molten carbonate fuel cells
MD—medium duty
MDHD— medium- and heavy-duty
MECA—Manufacturers of Emission Controls Association
MFCG—mobile fuel cell generatorMOA—Memorandum of Agreement
MOVES—Motor Vehicle Emission Simulator
MPa—MegaPascal
MPFI—Multi-Port Fuel Injection
MPG—miles per gallon
MPGde—miles per gallon diesel equivalent
MSRC—Mobile Source Air Pollution Reduction Review Committee
MSW—municipal solid wastes
MTA—Metropolitan Transportation Authority (Los Angeles County "Metro")
MW—megawatt
MWh—megawatt hour
MY—model year
NAAQS—national ambient air quality standards
NAFA—National Association of Fleet Administrators
NAICS—North American Industry Classification System
NFPA—National Fire Protection Association
NCP—nonconformance penalty
NEV—neighborhood electric vehicles
NextSTEPS—Next Sustainable Transportation Energy Pathways
NG/NGV—natural gas/natural gas vehicle
NGO—non-governmental organization
NH3—ammonia
Nitro-PAHs—nitrated polycyclic aromatic hydrocarbons
NHTSA—Natural Highway Traffic Safety Administration
NMC—nickel manganese cobalt
NMHC—non-methane hydrocarbon
NO—nitrogen monoxide
NO_2—nitrogen dioxide
$NO + NO_2$—nitrous oxide
NOPA—Notice of Proposed Award
NOx—oxides of nitrogen
NRC—National Research Council
NREL—National Renewables Energy Laboratory
NRTC—non-road-tested cycle
NSPS—new source performance standard
NSR—new source review
NTE—not-to-exceed
NZ—near zero
NZE – near zero emission
O3—ozone
OBD—on-board diagnostics
OCS—overhead catenary system
OCTA—Orange County Transit Authority
OEHHA—Office of Environmental Health Hazard Assessment
OEM—original equipment manufacturer
One-off—industry term for prototype or concept vehicle

LIST OF ACRONYMS (cont'd)

OP—opposed piston
OSAR—Onboard Sensoring and Reporting
PAH—polycyclic aromatic hydrocarbons
PAMS—portable activity measurement systems
PbA—lead acid
PCM—powertrain control module
PEMFC—proton exchange membrane fuel cell
PEMS—portable emissions measurement system
PEV—plug-in electric vehicle
PFI—port fuel injection
PHET—plug in hybrid electric tractor / plug-in hybrid electric truck
PHEV—plug-in hybrid vehicle
PM—particulate matter / permanent magnet
PM2.5—particulate matter ≤ 2.5 microns
PM10—particulate matter ≤ 10 microns
POH—Port of Hueneme
POLA—Port of Los Angeles
POLB—Port of Long Beach
PON—Program Opportunity Notice
POS—point of sale
ppb—parts per billion
ppm—parts per million
PSI—Power Solutions International
PTR-MS—proton transfer reaction-mass spectrometry
QCD—Quality Custom Distribution
QVM—qualified vehicle modifiers
R&D—research and development
RD&D—research, development and demonstration
RDD&D (or RD3)—research, development, demonstration and deployment
REAL—Real Emissions Assessment Logging
REMD—roadside emissions monitoring device
RFA—Renewable Fuels Association
RFI—Request for Information
RFP—Request for Proposal
RFS—renewable fuel standards
RH—refuse hauler
RI—reactive intermediates
RISC—reduced instruction set computer
RM—ramp metering
RMC—ramped modal cycle
RMC-SET— ramped modal cycle supplemental emissions test
RNG—renewable natural gas
ROG—reactive organic gases
ROI—return on investment
RPS—Rail Propulsion Systems
RTP/SCS—Regional Transportation Plan/Sustainable Communities Strategy
S2S—Shore to Store
SAE—Society of Automotive Engineers
SB—school bus / Senate Bill
SCAB—South Coast Air Basin or "Basin"
SCAG—Southern California Association of Governments
SCAQMD—South Coast Air Quality Management District
SCFM—standard cubic feet per minute
SCE—single cylinder engine / Southern California Edison Company / Southern Counties Express
SCR—selective catalytic reduction
SCRT—Selective Catalytic Regenerating Technology
SCCRT—Selective Catalytic Continuously Regenerating Technology
SDG&E—San Diego Gas & Electric Company
SHR—steam hydrogasification reaction
SI—spark ignited
SI-EGR—spark-ignited, stoichiometric, cooled exhaust gas recirculation
SIP—State Implementation Plan
SJVAPCD—San Joaquin Valley Air Pollution Control District
SMR—steam methane reforming
SNG—synthetic natural gas
SOAs—secondary organic aerosols
SOC—state-of-charge
SoCalGas—Southern California Gas Company (A Sempra Energy Utility)
SOFC—solid oxide fuel cells
SPaT—single phase and timing
START—Sustainable Terminals Accelerating Regional Transportation
STEPS3— Sustainable Transportation Energy Pathways 3
STTR—Small Business Technology Transfer
SULEV—super ultra-low emission vehicle
SUV—sports utility vehicle
SwRI—Southwest Research Institute
TAC—toxic air contaminants
TAO—Technology Advancement Office
TAP—(Ports') Technology Advancement Program
TB—transit bus
TC—total carbon
TCO—total cost of ownership
TEMS—transportable emissions measurement system
THC—total hydrocarbons
TLS—Toyota Logistics Services
TO—task order
tpd—tons per day
TRB—Transportation Research Board
TRL—technology readiness level
TSI—Three Squares, Inc.
TOU—time-of-use
TT—Turtle Top Bus

LIST OF ACRONYMS (cont'd)

TTSI—Total Transportation Services, Inc.
TWC—three-way catalyst
UCI—University of California, Irvine
UCLA— University of California, Los Angeles
UCR—University of California, Riverside
UCR/CE-CERT—UCR/College of Engineering/Center for Environmental Research & Technology
UDDS—urban dynamometer driving schedule
$\mu g/m^3$—microgram per cubic meter
ULEV—ultra low emission vehicle
ULSD—ultra low sulfur diesel
UPS—United Postal Service
U.S.—United States
U.S. EPA—United States Environmental Protection Agency
USTS—United States Training Ship
V2B—vehicle-to-building
V2G—vehicle-to-grid
V2G/B—vehicle-to-building functionality
VLS—variable speed limit
VMT—vehicle miles traveled
VOC—volatile organic compounds
V-PER—vessel performance management package
VPP—virtual power plant
WAIRE—Warehouse Actions and Investments to Reduce Emissions Program
WGS—water gas shift
WVU—West Virginia University
ZANZEFF—Zero and Near Zero Emission Freight Facilities
ZE—zero emission
ZEB—zero-emission bus
ZECT—Zero Emission Cargo Transport
ZEDT—Zero Emission Drayage Truck
ZET—zero emission truck
ZEV—zero emissions vehicle

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