South Coast
Air Quality
Management District

March 2020



# Clean Fuels Program

## 2019 Annual Report & 2020 Plan Update

### Technology Advancement Office

*Driving toward cleaner air*

**Cover Photo Credits**

Left to right; top to bottom

- Kenworth CNG Hybrid Electric Zero Emissions Capable Class 8 Demonstration Truck
- Class 8 Truck under Chassis Dynamometer Testing for Large-Scale, In-Use Emissions Study
- Charging of Light Duty Battery Electric Vehicle
- Volvo Class 8 Demonstration Truck for LIGHTS Project
- Liquid Hydrogen Storage Unit at OCTA for Heavy-Duty Vehicle Infrastructure Project
- Kenworth Hydrogen Fuel Cell Class 8 Demonstration Truck

# South Coast Air Quality Management District

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# South Coast Air Quality Management District

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# EXECUTIVE SUMMARY

## Introduction

The South Coast Air Quality Management District (South Coast AQMD) is the air pollution control agency for all of 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, 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 TAO Clean Fuels Program is an integral part of the South Coast AQMD's effort to achieve the significant NOx reductions called for in the 2016 Air Quality Management Plan (AQMP) because it affords the South Coast AQMD the ability to fund research, development, demonstration and accelerated deployment of clean fuels and transformative transportation technologies.

Using funding received through a $1 motor vehicle registration fee, the Clean Fuels Program encourages, fosters and supports clean fuels and transportation technologies, such as hydrogen and fuel cells, advanced natural gas 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, which allows significant leveraging of the 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 leveraged nearly $340 million into over $1.5 billion in projects.

As technologies move towards commercialization, such as battery electric trucks, the Clean Fuels Program has been able to partner with large original equipment manufacturers (OEMs), such as Daimler and Volvo, in order to eventually deploy these vehicles in large numbers. These partnerships with the OEMs 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 eventually into customers' hands. The OEMs have the resources and abilities to design, engineer, test, manufacture, market, distribute and service quality products under brand names that are trusted. To obtain the emission reductions needed to meet federal and state ambient air quality standards, large numbers of advanced technology clean-fueled vehicles must be deployed across our region and state.

While South Coast AQMD aggressively seeks to leverage funds, it continues to strive to play a leadership role in technology development and commercialization, along with its partners, to accelerate the reduction of criteria pollutants. As a result, the TAO Clean Fuels Program has traditionally supported a portfolio of technologies, in different stages of maturity, to provide a continuum of emission reductions and health benefits over time. This approach provides the greatest flexibility and enhances the region's chances toward achieving the National Ambient Air Quality Standards (NAAQS).

California Health and Safety Code (H&SC) 40448.5(e) calls for the Clean Fuels Program to consider, among other factors, the current and projected economic costs and availability of fuels, the cost-effectiveness of emission reductions associated with clean fuels compared with other pollution control

alternatives, the 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 the 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 the South Coast AQMD continue to make progress toward achieving its clean air goals.

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

# Setting the Stage

The overall strategy of TAO's Clean Fuels Program is based, in large part, on emissions reduction technology needs identified in the Air Quality Management Plan (AQMP) and the South Coast AQMD Board's directives to protect the health of the almost 18 million residents (nearly half the population of California) in the South Coast Air Basin (Basin). The AQMP, which is updated approximately every four years, is the long-term regional "blueprint" that relies on fair-share emission reductions from all jurisdictional levels (e.g., federal, state and local). The 2016 AQMP, which was adopted by the South Coast AQMD Board in March 2017, 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).

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 88 percent of the NOx emissions in this region, as shown in Figure 1. 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 ($\mu g/m^3$)], including secondary organic aerosols.

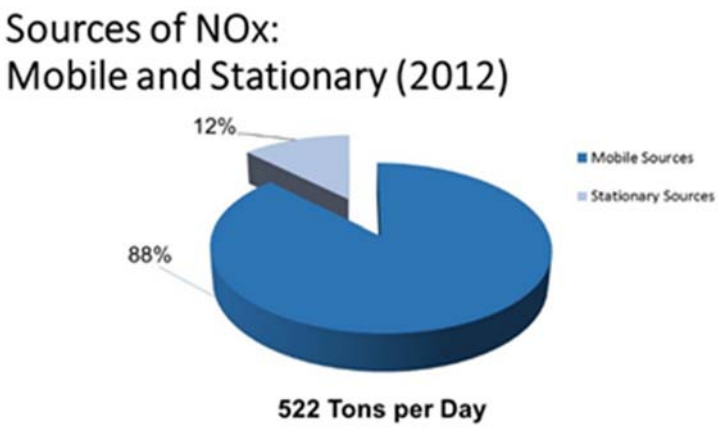


**Figure 1: Sources of NOx 2012 Base Year**

The emission reductions and control measures in the 2016 AQMP rely on a mix of currently available technologies as well as the expedited development and commercialization of lower-emitting mobile and stationary advanced technologies to achieve health-based air quality standards. The 2016 AQMP identifies a 45 percent reduction in NOx required by 2023 and an additional 55 percent reduction by 2031 to achieve ozone standards of 80 ppb and 75 ppb, respectively. Figure 2 illustrates these needed NOx reductions in the Basin. The majority of these NOx reductions must come from mobile sources, both on-road and off-road. Notably, the South Coast

AQMD is currently only one of two regions in the nation designated as an extreme nonattainment area (the other region is San Joaquin Valley).

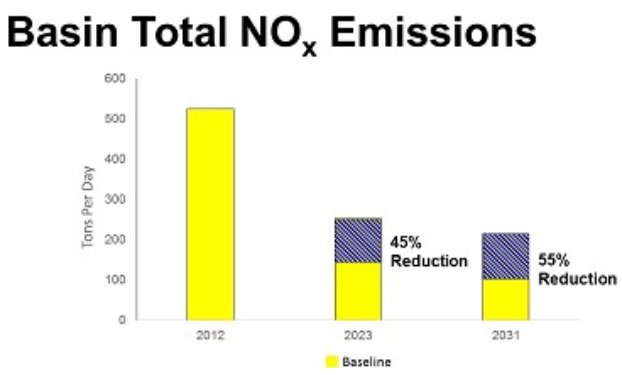


**Figure 2: Total NOx Reductions Needed**

For the first time, the 2016 AQMP identified a means to achieving the federal ambient standards through regulations and incentives for near-zero and zero emission technologies that are commercial or nearing commercialization. This strategy, however, requires a significantly lower state and national heavy-duty truck engine emissions standard with the earliest feasible implementation date, significant additional financial resources, and accelerated fleet turnover on a massive scale.

Current state efforts in developing regulations for on- and off-road vehicles and equipment are expected to reduce NOx emissions significantly, but not sufficiently to meet the South Coast AQMD needs, especially in terms of timing.

# Clean Fuels Program

The Clean Fuels Program is a very important mechanism to encourage and accelerate the advancement and commercialization of clean fuel and transportation 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 not only to provide a portfolio of technology choices but to achieve emissions reduction benefits in the near-term as well as over the longer term. The South Coast AQMD's Clean Fuels Program typically funds projects in the Technology Readiness Level (TRL) ranging between 3-8.


**Figure 3: Stages of Clean Fuels Program Funding**

Below is a summary of the 2019 Clean Fuels Annual Report and Draft 2020 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 serve, among other roles, to 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 typically attend and

provide feedback. Preliminary review and comment are also provided by South Coast AQMD's Board and other interested parties and stakeholders, as deemed appropriate.

## 2019 Annual Report

In CY 2019, the South Coast AQMD Clean Fuels Program executed 68 new contracts, projects or studies and modified 4 continuing project adding dollars toward research, development, demonstration and deployment projects as well as technology assessment and transfer of alternative fuel and clean fuel technologies. Table 1 (page 18) shows our major funding partners in CY 2019. Table 2 (page 32) lists the 72 projects or studies, which are further described in this report. The South Coast AQMD Clean Fuels Program contributed nearly $11.9 million in partnership with other governmental organizations, private industry, academia and research institutes, and interested parties, with total project costs of approximately $134 million. The $11.9 million includes $3.12 million recognized into the Clean Fuels Fund as pass-through funds from United States Environmental Protection Agency (U.S. EPA) Airshed Grant funds for a battery-electric shuttle bus replacement project. Table 3 (page 34) provides information on this outside funding received into the Clean Fuels Fund. Additionally, in CY 2019, the Clean Fuels Program continued to leverage other outside funding opportunities, securing new awards totaling $19.9 million from federal, state and local funding opportunities. Table 4 (page 34) provides a comprehensive summary of these federal, state and local revenues awarded to the South Coast AQMD during CY 2019. Like the last couple of years, the significant project scope of a few key contracts executed in 2019 resulted in higher than average leveraging of Clean Fuels dollars. Typical historical leveraging is $4 for every $1 in Clean Fuels funding. In 2019, South Coast AQMD continued this upward trend with more than $14 leveraged for every $1 in Clean Fuels funds. Leveraging dollars and aggressively pursuing funding opportunities is critical given the magnitude of needed funding identified in the 2016 AQMP to achieve federal ozone air quality standards.

The projects or studies executed in 2019 included a diverse mix of advanced technologies. The following core areas of technology advancement for 2019 executed contracts (in order of funding percentage) include:

1. Electric and Hybrid Vehicle Technologies and Related Infrastructure (emphasizing electric and hybrid electric trucks developed by OEMs and container transport technologies with zero emission operations);
2. Health Impacts Studies (including MATES V);
3. Technology Assessment and Transfer/Outreach;
4. Hydrogen and Mobile Fuel Cell Technologies and Infrastructure;
5. Fuel/Emissions Studies; and
6. Engine Systems/Technologies (emphasizing alternative and renewable fuels for truck and rail applications).

The chart on page 30 (Figure 17) shows the distribution by percentage of executed agreements in 2019 across these core technologies.

During CY 2019, the 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 the 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 electric and hybrid electric technologies and infrastructure to develop and demonstrate medium- and heavy-duty vehicles in support of transitioning to a near-zero and zero emissions goods movement industry; development, demonstration and deployment of large displacement natural gas and

ultra-low emissions engines; and demonstration of emissions control technologies for heavy-duty engines; and natural gas and renewable natural gas deployment and support.

In addition to the 72 executed contracts and projects, 15 research, development, demonstration and deployment projects or studies and 18 technology assessment and transfer contracts were completed in 2019, as listed in Table 6 (page 52). Appendix C includes two-page summaries of the technical projects completed in 2019. As of January 1, 2020, there were 128 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, 2020, after approval by the South Coast AQMD Board.

## 2020 Plan Update

Staff's re-evaluation of the Clean Fuels Program to develop the annual Plan Update is based on a reassessment of the technology progress and direction for the agency. The Program continually seeks to support the development and deployment of lower-emitting technologies with increased collaboration with OEMs in order to get to 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, emissions reduction potential and cofunding opportunities. For several years, the state has continued to focus a great deal of its attention on climate change and petroleum reduction goals, but the South Coast AQMD has necessarily remained committed to developing, demonstrating and commercializing technologies that reduce criteria pollutants, specifically NOx and toxic air contaminants (TACs). Fortunately, many, if not the majority, of these technologies that address the Basin's need for NOx and TAC reductions also garner reductions in greenhouse gases (GHG) and petroleum use. Due to these "co-benefits," the South Coast AQMD has been successful in partnering with the state, which allows the Clean Fuels Program to leverage its funding extensively.

To identify technology and project opportunities where funding can make a significant difference in deploying progressively cleaner technologies in the Basin, the South Coast AQMD employs several outreach and networking activities. These activities range from close involvement with state and federal collaboratives, partnerships and industrial coalitions, to the issuance of Program Opportunity Notices (PONs) to solicit project ideas and concepts as well as issuance of Requests for Information (RFIs) to determine the state of various technologies and the development and commercialization challenges faced by those technologies. 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 activities are included conceptually within the Draft 2020 Plan Update. On a related side note, because of Assembly Bill (AB) 617[1], which requires reduced exposure to communities most impacted by air pollution. TAO conducted additional outreach 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.

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 solutions to the emission control needs identified in the 2016 AQMP. Given the need for significant reductions over the next five to ten years, near-zero and zero emission technologies are emphasized. Areas of focus include:

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

- reducing emissions from port-related activities, such as cargo handling and container movement other technologies, including demonstration and deployment of zero emission drayage trucks;
- developing and demonstrating ultra-low emission, liquid fuel, larger displacement engines and zero emission heavy-duty vehicles;
- developing, demonstrating and deploying advanced natural gas engines and vehicles as well as near-zero and zero emission technologies for high horsepower applications;
- mitigating criteria pollutant emissions from renewable fuels, such as renewable natural gas, diesel and hydrogen as well as other renewable fuels and waste streams;
- producing transportation fuels and energy from renewable and waste stream sources;
- developing and demonstrating electric-drive (fuel cell, battery, plug-in hybrid and hybrid) technologies across light-, medium- and heavy-duty platforms;
- establishing large-scale hydrogen refueling and EV charging infrastructure to accelerate introduction of zero emission vehicles into the market; and
- developing and demonstrating advanced zero emission microgrids for energy storage and demand.

Table 7 (page 71) lists the potential projects across nine core technologies by funding priority:

1. Hydrogen/Mobile Fuel Cell Technologies and Infrastructure (especially large-scale refueling facilities);
2. Engine Systems/Technologies (emphasizing alternative and renewable fuels for truck and rail applications);
2. Electric/Hybrid Vehicle Technologies and Related Infrastructure (emphasizing electric and hybrid electric trucks and container transport technologies with zero emission operations);
4. Fueling Infrastructure and Deployment (predominantly natural gas and renewable fuels);
5. Stationary Clean Fuel Technologies (including microgrids and renewables);
6. Fuel and Emission Studies;
7. Emission Control Technologies;
8. Health Impact Studies; and
9. Technology Transfer/Assessment and Outreach.

These potential projects for 2020 total $16.1 million, with anticipated leveraging of more than $4 for every $1 of Clean Fuels funding for total project costs of $81.86 million. Some of the proposed projects may also be funded by revenue sources other than the Clean Fuels Program, especially VOC and NOx mitigation and incentive projects.

# 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 South Coast Air 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 the 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, 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 TAO Clean Fuels Program is an integral part of the South Coast AQMD's effort to achieve the significant NOx reductions called for in the 2016 AQMP.

California H&SC section 40448.5(e) calls for the Clean Fuels Program to consider, among other factors, the current and projected economic costs and availability of fuels, the cost-effectiveness of emission reductions associated with clean fuels compared with other pollution control alternatives, the 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 the 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 the 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), the South Coast AQMD must submit to the Legislature, on or before March 31 of each year, an annual report that includes:

1. A description of the core technologies that the 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. An analysis of the impact of the 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 the South Coast AQMD;
3. A description of projects funded by the South Coast AQMD, including a list of recipients, subcontractors, cofunding 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. The title and purpose of all projects undertaken pursuant to the Clean Fuels Program, the names of the contractors and subcontractors involved in each project and the amount of money expended for each project;
5. A summary of the 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 project.

Furthermore, H&SC section 40448.5.1(a)(2) requires the 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, the 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, the scientific community and environmental impacts. The Technology Advancement Advisory Group serves to:

- Coordinate the South Coast AQMD 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, including consulting with regarding approval of the required annual report prior for submittal to the South Coast AQMD Governing Board. Also, in 1999, considering the formation of the SB 98 Clean Fuels Advisory Group, the South Coast AQMD also 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, the scientific community and environmental interests. Traditionally, there has been exactly 12 members on this advisory group, but this year staff is recommending to the Board's Technology Committee that it add representatives from the Ports of Long Beach and Los Angeles, as both entities have been integral players and stakeholders in demonstrating near-zero and zero emissions technologies in and around the ports and surrounding environmental justice communities.

As needed, 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. The current members of the SB 98 Clean Fuels Advisory Group and Technology Advancement Advisory Group (as of 2/14/20) 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 the 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) a 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) finally submittal of the Clean Fuels Program Annual Report and Plan Update to the Legislature by March 31 of every year.

# The Need for Advanced Technologies & Cleaner Fuels

Achieving federal and state clean air standards in Southern California 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 88 percent of the NOx emissions in this region, as shown in Figure 1. 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.

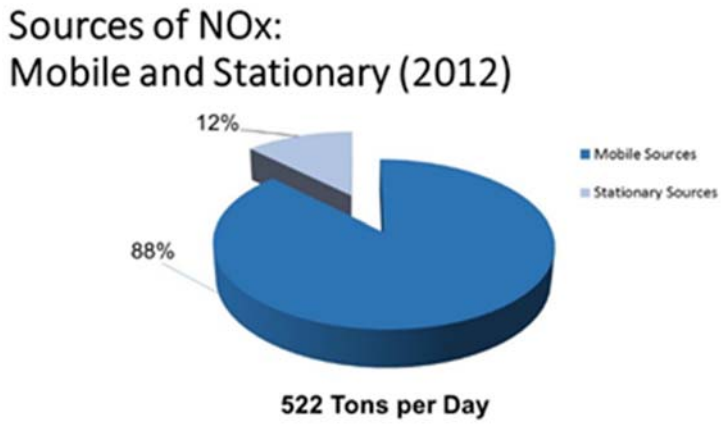


**Figure 1: Sources of NOx 2012 Base Year**

To fulfill near -and long-term emissions reduction targets, the 2016 AQMP relies on a mix of currently available technology as well as the expedited development and demonstration of advanced technologies that are not yet ready for commercial use. Significant reductions are anticipated from implementation of advanced control technologies for both on-road and off-road mobile sources. In addition, the air quality standards for ozone (70 ppb, 8-hour average) and fine particulate matter, promulgated by the U.S. EPA, are projected to require additional long-term control measures for both NOx and VOC.

The need for advanced mobile source technologies and clean fuels is best illustrated by Figure 2 (page 4) which identifies just how far NOx emissions must be reduced to meet federal standards by

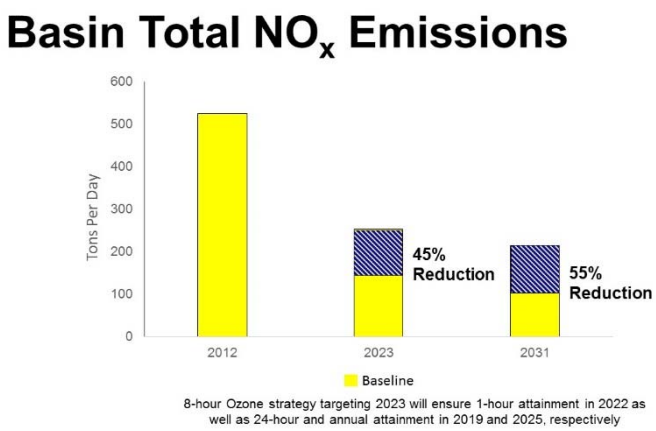


**Figure 2: Total NOx Reductions Needed**

2023 and 2031. The 2016 AQMP's estimate of needed NOx reductions will require the South Coast AQMD Clean Fuels Program to encourage and accelerate advancement of clean transportation technologies that are used as control strategies in the AQMP. Given this contribution, significant cuts in pollution from these sources are needed, therefore proposed AQMP mobile source strategies call for establishing requirements for cleaner technologies (both zero and near-zero) and deploying these technologies into fleets, requiring cleaner and renewable fuels, and ensuring continued clean performance in use. Current state efforts in developing regulations for on- and off-road vehicles and equipment are expected to reduce NOx emissions significantly, but not sufficiently to meet the South Coast AQMD needs, especially in terms of timing.

Health studies also indicate a greater need to reduce NOx emissions and toxic air contaminant emissions. For example, the goal of South Coast AQMD's Multiple Air Toxics Exposure Study (MATES) IV, completed in 2015, like the prior three MATES efforts, was to assess air toxic levels, update risk characterization, and determine gradients from selected sources. However, MATES IV added ultrafine PM and black carbon monitoring components as well. The study found a dramatic decrease in ambient levels of diesel particulate matter and other air toxics. Diesel PM was still the major driver of air toxics health risks. While the levels and exposures decreased, a revision to the methods used to estimate cancer risk from toxics developed by the California Office of Health Hazard Identification increased the calculated risk estimates from these exposures by a factor of up to three. In late 2017, South Coast AQMD initiated MATES V to update the emissions inventory of toxic air contaminants and modeling to characterize risks, including measurements and analysis of ultrafine particle concentrations from major roadways and the regional carcinogenic risk from exposure of air toxics. The MATES V report is expected to be finalized by the end of 2020.

In summary, advanced, energy efficient and renewable technologies are needed not only for attainment, but also to protect the health of those who reside within the South Coast AQMD's jurisdiction, 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 the federal air quality goals. To help 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 Technology Advancement Office (TAO).

As technologies move towards commercialization, such as battery electric trucks, the Clean Fuels Program has been able to partner with large original equipment manufacturers (OEMs), such as Daimler and Volvo, in order to eventually deploy these vehicles in large numbers. These partnerships with the OEMs 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 eventually into customers' hands. The OEMs have the resources and abilities to design, engineer, test, manufacture, market, distribute and service quality products under brand names that are trusted. To obtain the emission reductions needed to meet federal and state ambient air quality standards, large numbers of advanced technology clean-fueled vehicles must be deployed across our region and state.

Once advanced technologies and cleaner fuels are commercial-ready, there needs to be a concerted effort to get them into the marketplace and ono the roads. The South Coast AQMD's Carl Moyer Program, which was launched in 1988, helps achieve these results. The two programs produce a unique synergy, with the Carl Moyer Program (and other incentive programs, such as Proposition 1B-Goods Movement and the Community Air Protection Program[2]) providing incentives to push market penetration of the technologies developed and demonstrated by the Clean Fuels Program. This synergy enables the 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 a concern given the magnitude of additional funding identified in the 2016 AQMP to achieve federal ozone air quality standards.

The following sections describe program funding, provide a 2019 overview and describe core technologies of 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 the South Coast AQMD. This revenue is typically about $13.5 million and $350,000, respectively, every year. For CY 2019, the funds available through each of these mechanisms were as follows:

- Mobile sources (DMV revenues) $13,877,184
- Stationary sources (emission fee surcharge) $349,876

The South Coast AQMD 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 the California Air Resources Board (CARB), the California Energy Commission (CEC), the U.S. EPA (including but not limited to their Diesel Emissions Reduction Act or DERA, the Clean Air Technology Initiative or CATI, and Airshed programs), the U.S. Department of Energy (DOE) and the 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 3 (page 34) lists the supplemental grants and revenues totaling $3.12 million for contracts executed in CY 2019.

Table 4 (page 34) lists the federal and state revenue totaling nearly $20 million awarded to the South Coast AQMD in 2019 for projects that are part of the overall Clean Fuels Program's RD[3] efforts, even if for financial tracking purposes the revenue is recognized into another special revenue fund other than the Clean Fuels Fund (Fund 31).

[2] http://www.aqmd.gov/home/programs/business/business-detail?title=vehicle-engine-upgrades

The final and perhaps most significant funding source can best be described as an indirect source, i.e., funding not directly received by the South Coast AQMD. This indirect source is the cost-sharing provided by private industry and other public and private organizations. In fact, these 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 Technology Advancement Office 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 $340 million into more than $1.5 billion in projects. For 2019, the Clean Fuels Program leveraged each $1 to more than $14 of outside funding. Similar to last year, this atypical leverage was the result of a few key contracts with significant project scopes executed in 2019, such as the $91 million project with Volvo, which includes a nearly $45 million award to the South Coast AQMD from CY 2018 (see the Project Summaries by Core Technologies for more information on these key projects, as well as the project highlights in the Strategy and Impact section starting on page 17). Through these public-private partnerships, the South Coast AQMD has shared the investment risk of developing new technologies along with the benefits of expedited development and commercial availability, increased end-user acceptance, reduced emissions from the demonstration projects and ultimately increased use of clean technologies in the Basin. While the 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 2016 AQMP to achieve federal ozone air quality standards. The South Coast AQMD's 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 2019 are listed in Table 1 (page 18).

# 2019 Overview

This report summarizes the progress of the South Coast AQMD Clean Fuels Program for CY 2019. The South Coast AQMD Clean Fuels Program cost-shares projects to develop and demonstrate zero, near-zero and low emissions clean fuels and advanced technologies to push the state-of-the-technology and promote commercialization and deployment of promising or proven technologies not only for the Basin but Southern California and the nation as well. As noted, 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 South Coast AQMD Clean Fuels Program in CY 2019. During the period between January 1 and December 31, 2019, the South Coast AQMD executed 68 new contracts/agreements, projects or studies and modified 4 continuing project adding dollars during CY 2019 that support clean fuels and advanced zero, near-zero and low emission technologies (see Table 2, page 32). The South Coast AQMD Clean Fuels Program contribution for these projects was nearly $12 million, inclusive of $3 million received into the Clean Fuels Fund as cost-share for one contract executed in this reporting period. Total project costs are nearly $134 million. These projects 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 (summarized in Table 3, page 34), but also funds awarded to the 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 $20 million in 2019, see Table 4, page 34). For example, in 2018, the South Coast AQMD was awarded nearly $45 million by CARB as project partner with Volvo on their Low Impact Green Heavy Transportation Solutions (LIGHTS) Project, which has an overall project cost of over $100 million and

will advance and hopefully commercialize electric truck technology. In the 2018 Annual Report reflected this $45 million award. In CY 2019, the contract with Volvo was executed so it's reflected in Project Summaries (which begin on page 35); in fact, given its significance, the Volvo LIGHTS Project is included in project highlights in this Annual Report (page 18). More details on this financial summary can be found later in this report. The South Coast AQMD will continue to pursue federal, state and private funding opportunities in 2020 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 (especially large-scale refueling facilities);
- Engine Systems/Technologies (emphasizing alternative and renewable fuels for truck and rail applications);
- Electric/Hybrid Vehicle Technologies and Related Infrastructure (emphasizing electric and hybrid electric trucks and container transport technologies with zero emission operation);
- Fueling Infrastructure and Deployment (predominantly natural gas 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 2020 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 2020.

The 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.

The 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 cofunding opportunities. Although the South Coast AQMD program is significant, national and international activities affect the direction of technology trends. As a result, the South Coast AQMD program must be flexible to leverage and accommodate these changes in state, national and international priorities. Nonetheless, while the 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 greenhouse gas (GHG) reductions. Due to these "co-benefits," the South Coast AQMD has been successful in partnering with the state and federal government. Even with the leveraged funds, the challenge for the 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, the 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 Program Opportunity Notices (PONs) to solicit project ideas and concepts as well as the issuance of Requests for Information 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, medium- and heavy-duty 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., natural gas, propane and hydrogen) including their 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 heavy- and medium-duty 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. The 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 as they relate to goods movement. In the absence of regulatory authority, the 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 2016 AQMP included five Facility-Based Mobile Source Measures, also known as indirect source measures. Since then, 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, indirect source measures for warehouses could focus on reducing emissions from trucks servicing the facility. 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 heavy-duty diesel earth-moving vehicles.

Specific projects are selected for cofunding 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 the South Coast AQMD programs that meet both the funding constraints and 2016 AQMP needs for achieving clean air are briefly described below.

## Hydrogen/Mobile Fuel Cell Technologies and Infrastructure

Toyota and Hyundai commercialized light-duty fuel cell vehicles in 2015. Honda started delivering their Fuel Cell Clarity in 2016, and others have plans to commercialize their own soon. As automakers continue to collaborate on development efforts (e.g., Honda and GM) and commercialize fuel cell vehicles, in the interim plug-in hybrid technology could help enable fuel cells by using larger capacity batteries until fuel cell components mature. For example, Mercedes-Benz announced limited production of a plug-in fuel cell model GLC for 2018 in Germany, with U.S. availability to follow. However, the greatest challenge for the viability of fuel cell vehicles remains the installation and operations of hydrogen fueling stations. AB 8 requires the 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 65 stations funded by CEC and CARB by the end of 2019, partially funded by South Coast AQMD for those in our region, there is one legacy and 39 retail operational in California, but most if not all 65 are expected to be operational by the end of 2020 with capacity for more than 10,000 fuel cell vehicles. 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: 2019 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California*[3] released in December 2019 covering 2019 findings states that there were 6,826 fuel cell vehicles registered in California by October 2019. However, CARB's 2017 Annual Evaluation projects 13,400 fuel cell electric vehicles (FCEVs) in California by 2020 and 37,400 by the end of 2023. 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 to expand the market with heavy-duty technologies and their infrastructure.

Clearly, the South Coast AQMD must continue to support infrastructure required to refuel retail fuel cell vehicles and the nexus to medium- and heavy-duty trucks including reducing the cost to deploy heavy-duty hydrogen infrastructure. To that end, South Coast AQMD has cofunded 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 $500,000 has been committed towards the CARB Zero and Near Zero-Emission Freight Facilities (ZANZEFF) Shore-to-Shore project to deploy 10 heavy-duty fuel cell trucks and install three heavy-duty hydrogen stations in Wilmington and Ontario; this contract will be executed in 2020. 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 Zero Emission Cargo Transport (ZECT) project (phase 2 or ZECT 2), to develop and deploy six heavy-duty fuel cell drayage trucks. Two of the fuel cell drayage trucks are manufactured by Transportation Power Inc. (TransPower), two fuel cell trucks by US Hybrid, one fuel cell truck by Kenworth, and one fuel cell truck by Hydrogenics (a Cummins Inc. company). Six of the seven vehicle designs, and integration, are completed, and four of the fuel cell drayage trucks are in demonstration. The battery and fuel cell dominant fuel cell trucks have a range of 150-200 miles.

## Engine Systems/Technologies

Medium- and heavy-duty on-road vehicles contributed approximately 33 percent of the Basin's NOx based on 2016 AQMP data. More importantly, on-road heavy-duty diesel trucks account for 33 percent

[3] https://ww2.energy.ca.gov/2019publications/...2019.../CEC-600-2019-039. pdf

of the on-road mobile source PM2.5, a known toxic air contaminant (TAC). Furthermore, according to CARB, trucks and buses are responsible for 37 percent of California's greenhouse gases (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 heavy-duty sector, to attain the federal clean air standards. Even with the announced rollout of zero emission trucks beginning 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 heavy-duty vehicles can provide significant reductions in NOx and particulate emissions. The current NOx emissions standard for heavy-duty engines is 0.2 g/bhp- hr. The South Coast AQMD, along with various local, state and federal agencies, continues to support the development and demonstration of alternative-fueled low emission heavy-duty engine technologies, using natural gas, renewable natural gas or hydrogen, renewable diesel and potentially other renewable or waste stream fuels, for applications in heavy-duty 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 medium-duty gasoline engine to near-zero NOx level by using natural gas and propane.

In connection with the challenge to develop cleaner engine systems, on June 3, 2016, South Coast AQMD petitioned the U.S. EPA to initiate rulemaking for a lower NOx national standard for heavy-duty engines. The U.S. EPA has since acknowledged a need for additional NOx reductions through a harmonized and comprehensive national NOx reduction program for heavy-duty on-highway engines and vehicles. U.S. EPA announced the Cleaner Truck Initiative on November 13, 2018, and Advance Notice of Proposed Rule on January 6, 2020, to reduce NOx emissions from on-road heavy-duty trucks starting as early as model year 2026. CARB forged ahead, announcing its own Low NOx Omnibus rule, which may be before the CARB Board as early as Spring 2020, proposing a lower NOx standard starting model year 2024. Although both announcements are welcome news, the timing is too late to help the South Coast AQMD meet its 2023 federal attainment deadline. So, despite progress, commercialization and deployment of near-zero engines are still needed.

## Electric/Hybrid Vehicle Technologies and Infrastructure

There has been an increased level of activity and attention on electric and hybrid vehicles due to a confluence of factors, including the highly successful commercial introductions of hybrid light-duty passenger vehicles and more recently plug-in electric vehicles (PEVs) by almost all major automakers and increased public attention on global warming, as well as several Executive Orders issued by Former Governor Brown, such as his January 26, 2018 order, calling for 5 million ZEVs by 2030.

EV adoption continues to increase in 2017, selling more than 655,000 cumulative electric vehicles by September 2019 in California, according to Veloz (formerly the PEV Collaborative), with increasingly more announcements by international automakers (e.g., Mercedes-Benz, Volkswagen-Audi-Porsche, Hyundai/Kia, Ford, GM and several growing Chinese brands) on a variety of electrification plans, including some with extended zero emissions range. Joining the trend with longer-range battery electric light-duty passenger vehicles by Tesla, Chevy and several others, multiple manufacturers have announced light-duty electric truck development.

However, technology transfer to the medium- and heavy-duty applications is just beginning, especially in goods movement demonstrations in this region. As with hydrogen and fuel cell technologies, South Coast AQMD is actively pursuing research, development and demonstration projects for medium- and heavy-duty battery electric vehicles and their commercialization. South Coast AQMD is administering the DOE funded ZECT project to develop and demonstrate battery electric and plug-in hybrid drayage trucks: four battery electric trucks from TransPower, two battery electric trucks from US Hybrid, two

series plug-in hybrid electric trucks from TransPower, and three parallel plug-in hybrid electric trucks from US Hybrid. Battery electric trucks have an all-electric range of up to 100 miles and plug-in hybrid electric trucks have a range of up to 250 miles. This first ZECT project (ZECT 1), which is wrapping up, gave birth to many other EV and hybrid truck projects including the Greenhouse Gas Reduction Fund (GGRF) Zero Emission Drayage Truck (ZEDT) project demonstrating more than 40 electric and hybrid drayage trucks across California. In the ZEDT project, TransPower continued their development of their electric truck platform with their OEM partner Peterbilt. In addition, Clean Fuels has cofunded the Daimler and Volvo battery electric trucks. Daimler has deployed 14 Class 8 eCascadia and three Class 6 eM2 trucks in 2019 and installed seven DC fast charging stations at fleet locations. Volvo has deployed two Class 8 rigid trucks and three Class 8 60,000-pound tractors and installed two 50 kW DC fast charging stations at its TEC Fontana dealership in December 2019.

Lastly, the same electric and hybrid technology transfer is beginning to appear on off-road and marine applications. South Coast AQMD is currently in the process of demonstrating a battery electric excavator and wheel loader with Volvo Construction Equipment as part of a FY 18 U.S. EPA Targeted Airshed Grant award. At the same time, a new electric drive, diesel hybrid tugboat is in the process of construction and demonstration by fleet operator Harley Marine Services with cofunding from Port of Long Beach and CARB. These pilot demonstration projects are key to additional emission reductions from the off-road 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 natural gas 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 natural gas (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 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 the 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 heavy-duty diesel engines, depending on the duty-cycle. South Coast AQMD is performing a three-year in-use emissions study of 200 next-generation technology heavy-duty vehicles in the South Coast Air Basin. This study, expected to be completed in 2020, is aimed at understanding the activity pattern of different vocations, understanding the real-world emissions emitted from different technologies. Another study launched in 2020 will evaluate the emissions produced using alternative diesel blends in off-road heavy-duty engines.

## 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 the 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 the U.S. EPA and CARB, both agencies are currently planning research efforts to aid the next round of rulemaking 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 a number of 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 natural gas, 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 the 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[4], which requires reduced exposure to communities most impacted by air pollution, required TAO to carry out additional outreach in CY 2019 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 Port of Long Beach EV Blueprint, Los Angeles County EV Blueprint, City of Los Angeles Zero Emissions 2028 Roadmap, Electric Power Research Institute (EPRI) study on air quality and GHG impacts of residential electrification, and Los Angeles Cleantech Incubator projects. Technology transfer efforts also include support for various clean fuel vehicle incentive programs (i.e., Carl Moyer Program, Proposition 1B-Goods Movement, etc.). Furthermore, general and, when appropriate, targeted outreach is an effective part of any 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 CARB's Low Carbon Transportation Heavy-Duty Project Showcase in March, the SoCal Work Truck Show in October, and Riverside and Santa Monica AltCar events in October and November. While South Coast AQMD's Local Government, 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 13 for a description of the technology assessment and transfer contracts executed in CY 2019 as well as a listing of the 23 conferences, workshops and events funded in CY 2019. Throughout the year, staff also participates in various programmatic outreach for the various incentive programs implemented by TAO, including the Carl Moyer Program, Proposition 1B-Goods Movement, Volkswagen Mitigation Program, Replace Your Ride, a U.S. EPA Airshed-funded Commercial Electric Lawn and Garden Incentive and Exchange Program, and residential lawn mower and EV charger rebate programs, to name a few.

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

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# 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

**Project-Specific Issues**

- Identifying a committed demonstration site
- Overall project cost and cost-share using public monies
- Securing the fuel
- Identifying and resolving real and perceived safety issues
- Quantifying the actual emissions benefits
- Viability of the technology provider

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. The 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 the key stakeholders have become 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, for example, can contribute technology production expertise as well as the experience required for compatibility with process operations. Academic and research institutes bring state-of-the- technology knowledge and testing proficiency. Governmental and regulatory agencies can provide guidance in identifying sources with the greatest potential for emissions reduction, assistance in permitting and compliance issues, coordinating of infrastructure needs and facilitation of standards setting and educational outreach. Often, there is considerable synergy in developing technologies that address multiple goals of public and private bodies regarding the 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, both manufacturers and end-users tend to be discouraged from considering advanced technologies. The Clean Fuels Program addresses these needs by cofunding research, development, demonstration and deployment projects to share the risk of emerging technologies with their developers and eventual users.

Figure 3 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 technology choices but to achieve emission reduction benefits in the nearer as well as over the longer term. The South Coast AQMD Clean Fuels Program funds projects in the Technology Readiness Level ranging between 3-8.


**Figure 3: Stages of Clean Fuels Program Projects**

Due to the nature of these advanced technology research, development, demonstration and deployment ($RD^3$) projects, the benefits are difficult to quantify since their full emissions reduction potential may not be realized until sometime in the future, or perhaps not at all if displaced by superior technologies. Nevertheless, a good indication of the impact and benefits of the Clean Fuels Program overall is provided by this selective list of sponsored projects that have resulted in commercialized products or helped to advance the state-of-the-technology.

➢Near-zero NOx Engine Development for Heavy-Duty Vehicles
- Cummins Westport: low-NOx natural gas ISL G 8.9L and 12L engines (0.2 & 0.02 g/bhp-hr);
- SwRI project to develop a near-zero NOx Heavy-duty diesel engine; and
- Kenworth CNG Hybrid Electric Drayage Truck project.

➢Fuel Cell Development and Demonstrations
- Kenworth Fuel Cell Range Extended Electric Drayage Truck project;
- New Flyer Fuel Cell Transit Bus and Air Products Liquid Hydrogen Station at OCTA;
- Retail light-duty passenger fuel cell vehicles (Toyota Mirai, Hyundai Nexo, Honda Clarity);
- SunLine Transit Agency Advanced Fuel Cell Bus projects;
- Commercial stationary fuel cell demonstration with UTC and SoCalGas (first of its kind);
- UPS demonstration of fuel cell delivery trucks; and
- Fuel cell Class 8 trucks under Zero Emission Cargo Transport (ZECT) II Program.

➢Electric and Hybrid Electric Vehicle Development and Demonstrations
- Daimler Class 6 and 8 battery electric trucks with Penske and NFI;
- Volvo Class 8 battery electric trucks with TEC Fontana, DHE, and NFI;
- Hybrid electric delivery trucks with NREL, FedEx and UPS;
- Plug-in hybrid work truck with Odyne Systems;
- BYD battery-electric transit bus and trucks (yard hostlers and drayage);
- LA Metro battery electric buses;
- Blue Bird Electric School Bus with Vehicle to Grid (V2G) capability;
- TransPower Electric school buses, including V2G capability;
- TransPower/US Hybrid battery electric heavy-duty truck and yard hostlers; and
- Peterbilt battery-electric drayage trucks.

- Aftertreatment Technologies for Heavy-Duty Vehicles
  - Johnson Matthey and Engelhard trap demonstrations on buses and construction equipment;
  - Johnson Matthey SCRT and SCCRT NOx and PM reduction control devices on heavy-duty on-road trucks; and
  - Southwest Research Institute development of aftertreatment for heavy-duty 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 (page 2), the 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 South Coast AQMD program with a number of state and federal government organizations, including CARB, CEC, U.S. EPA and DOE/DOT and several of the 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 APCD and San Joaquin Valley APCD, as well as the National Association of Fleet Administrators (NAFA), major local transit districts, local gas and electric utilities, national laboratories, the San Pedro Bay Ports and several universities with research facilities, including but not limited to California State University Los Angeles, Purdue University, Universities of California Berkeley, Davis, Irvine, Los Angeles and Riverside, and University of West Virginia. The list of organizations with which the South Coast AQMD coordinates research and development activities also includes organizations specified in H&SC Section 40448.5.1(a)(2).

In addition, the South Coast AQMD holds periodic meetings with several organizations specifically to review and coordinate program and project plans. For example, the 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 the CaFCP, the California Stationary Fuel Cell Collaborative, the California Natural Gas Vehicle Partnership (CNGVP), EPRI, Veloz (formerly the PEV Collaborative), the Los Angeles Cleantech Incubator's Regional Transportation Partnership, the California Hydrogen Business Council (CHBC), the SoCalEV Collaborative and the West Coast Collaborative The coordination efforts with these various stakeholders have resulted in several cosponsored projects.

Descriptions of some of the key contracts executed in CY 2019 are provided in the next section of this report. It is noteworthy that most of the projects are cosponsored by various funding organizations and include the active involvement of original equipment manufacturers (OEMs). Such partnerships are essential to address commercialization barriers and to help expedite the implementation of advanced low emission technologies. Table 1 below lists the 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 participants who make important contributions critical to the success of the South Coast AQMD program. These partners are identified in the more detailed 2019 Project Summaries by Core Technologies (beginning page 35) contained within this report, as well as Table 4 (page 34) which lists

federal, state and local funding awarded to the South Coast AQMD in CY 2019 for RD$^3$ projects (which will likely result in executed project contracts in 2020).

**Table 1: South Coast AQMD Major Funding Partners in CY 2019**

| Research Funding Organizations | Major Manufacturers/Technology Providers |
|---|---|
| California Air Resources Board | Cummins Inc. |
| California Energy Commission | Daimler Trucks North America |
| Department of Energy | Long Beach Container Terminal |
| National Renewable Energy Laboratory | Mercedes-Benz USA |
| U.S. Environmental Protection Agency | Ports of Los Angeles & Long Beach |
| **Local Entities & Utilities** | San Pedro Bay Ports |
| MSRC/AB 2766 Discretionary Program | SSA Marine Terminal |
| San Joaquin APCD | Volvo Technology of America LLC |
| Southern California Gas Company | |

The following two subsections broadly address the South Coast AQMD's impact and benefits by describing specific examples of accomplishments including commercial or near-commercial products supported by the Clean Fuels Program in CY 2019. Such examples are provided in the following sections on the Technology Advancement Office's Research, Development and Demonstration projects and Technology Deployment and Commercialization efforts.

## Research, Development and Demonstration

Important examples of the impact of the South Coast AQMD research and development coordination efforts in 2019 include: (a) Demonstrate Zero Emission Trucks and EV Infrastructure (Volvo LIGHTS Project); (b) Demonstrate Zero Emission Cargo Handling Equipment; (c) Continued Development of Natural Gas Engine Emissions and Efficiency Improvements; and (d) Development of Fuel Cell-Gas Turbine Hybrid Technology.

### Demonstrate Zero Emission Trucks and EV Infrastructure

Volvo Trucks North America (Volvo), the second largest manufacturer of heavy-duty trucks, proposed a ground-breaking $91 million project called Volvo Low Impact Green Heavy Transport Solutions (LIGHTS). South Coast AQMD applied for a CARB Low Carbon Transportation grant and was awarded $44.8 million to administer the project, with an additional $4 million cost-share from South Coast AQMD through the Clean Fuels Program. Volvo and its partners provided the remaining $42 million. South Coast AQMD previously worked with Volvo on a DOE-funded project to develop a prototype Class 8 plug-in hybrid electric diesel truck with significantly reduced NOx emissions. Volvo continued to refine the plug-in hybrid electric diesel truck under an earlier CARB-funded GGRF Zero Emission Drayage Truck (ZEDT) project, with Coordinated Intelligent Transportation System (C-ITS) Eco-Drive software and geofencing capabilities to enable the truck to optimize NOx reductions and drive in zero emissions mode while operating in disadvantaged/environmental justice (EJ) communities. The Volvo LIGHTS project is Volvo's first endeavor into pilot and production Class 8 battery electric trucks in North America, with the first of these trucks being demonstrated at freight handling facilities in the Inland Empire.

While the environmental benefits of electric drive vehicles are widely accepted, the cost and durability of the technology as well as installation of charging infrastructure to support these vehicles, needs to be carefully analyzed and considered. There is also a need for regulatory agencies and OEMs to collect and analyze operational data on vehicles and infrastructure to evaluate the extent to which vehicle and infrastructure technologies are meeting the operational needs of fleets.

Under the Volvo LIGHTS project, Volvo will develop 8 pilot and 15 production level Class 8 battery-electric heavy-duty trucks and demonstrate them at Dependable Highway Express (DHE) in Ontario and NFI Industries in Chino. These trucks will be utilized in real-world commercial fleet operations in


**Figure 4: Overview of Volvo LIGHTS Project**

and around EJ communities and the Ports within the Basin. In addition, the Volvo LIGHTS project will deploy 29 battery electric forklifts, yard tractors and EVs, 59 Level 2 and DC fast chargers, and 1.8 MWh of solar. The Volvo LIGHTS project is expected to result in 3.57 tons/year of weighted emission reductions in NOx, ROG, and PM, and 3,020 tons/year of GHG reductions. Over the ten-year expected lifetime of the vehicles, this equates to 35.7 tons per year of NOx, ROG, and PM emission reductions, and 30,200 tons of GHG reductions. The project partners and main components of the Volvo LIGHTS project are in Figure 4 above.

The University of California Riverside (UCR/CE-CERT) and CALSTART Inc., contracts with which will be executed in 2020, will gather and analyze data from the trucks, forklifts, yard tractors, support electric vehicles, charging infrastructure and solar to evaluate performance under specific duty-cycles. Three configurations of the trucks will be produced including rigid trucks and 60,000 to 80,000-pound tractors. Volvo will utilize data from the pilot vehicles to inform development of the production vehicles. Volvo deployed two rigid trucks and three tractors to California in December 2019 and is extensively testing these vehicles prior to deployment at DHE and NFI in 2020.

The trucks have an all-electric range of 100-150 miles, with two electric drive motors with 370 kW maximum power and a two-speed transmission. The trucks have a 6x4 axle configuration, and the battery system provides 320 kWh of usable power. The Class 8 trucks are capable of utilizing 50 kW and 150 kW DC fast charging with CCS Type 2 connectors, with the production trucks having additional AC on-board charging capability to provide flexible charging options such as overnight charging for fleets. Figure 5 shows the Volvo LIGHTS trucks undergoing testing in Southern California.

**Figure 5: Volvo LIGHTS Trucks in California**

Facility upgrades will also take place at DHE and NFI fleet locations, as well as the TEC Fontana and La Mirada Volvo dealerships, to fully support the trucks. Two 50 kW DC fast chargers have already been installed at TEC Fontana (see Figure 6 below) and installation for the 150 kW DC fast charger will be completed in February 2020. Volvo is also hosting a technology showcase in February 2020 at TEC Fontana and the Fontana Speedway with a commercial fleet ride-and-drive opportunity for funding agencies, fleets and the media to highlight the technologies on the trucks, charging infrastructure, and service and support of these trucks. Installation of charging infrastructure, solar, and facility upgrades at DHE and NFI will take place later in 2020. In anticipation of charging infrastructure, these fleets have already ordered or received battery electric forklifts, yard tractors and support EVs.

The Volvo LIGHTS project showcases an opportunity for two major fleets in the Inland Empire to utilize an entirely zero emissions freight handling drayage operation throughout the goods movement supply chain, with Class 8 battery electric trucks handling drayage operations to and from the Ports of Los Angeles and Long Beach, to staging by battery electric yard tractors and unpacking by battery electric forklifts. When cargo is repacked, it will be delivered locally or regionally using battery electric trucks. The entire life cycle of zero emissions freight handling operations will be further enhanced

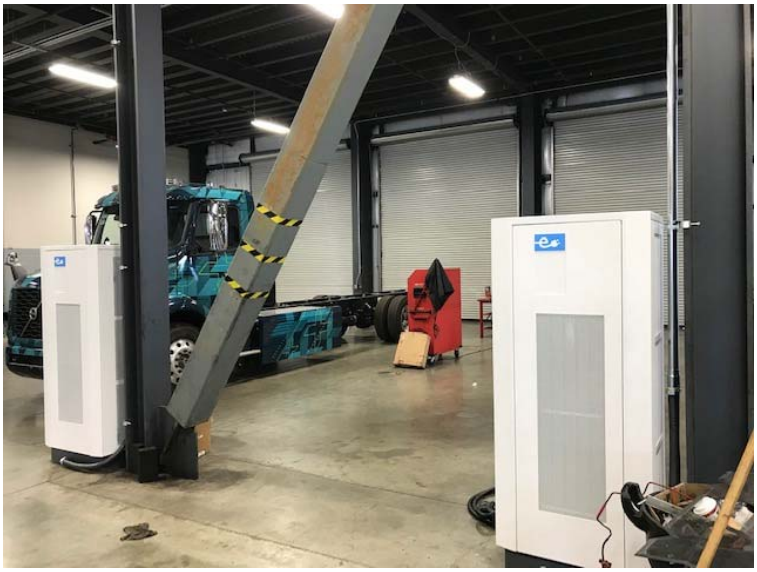

**Figure 6: Two 50 kW DC Fast Chargers at TEC Fontana**

by facility upgrades, such as electrical infrastructure and energy efficiency to enable charging infrastructure, solar, energy storage, and smart charging and energy management software to minimize grid impacts and costs to fleets. DHE and NFI are full-service logistics providers handling drayage, third-party logistics, and warehousing and distribution operations. These fleets will serve as models for other fleets in how to effectively scale up electrification of their operations.

**Demonstrate Zero Emission Cargo Handling Equipment**

In the last couple of years, the South Coast AQMD has provided cofunding on several zero emission cargo handling demonstration projects at the Ports of Los Angeles (POLA) and Long Beach (POLB) through its Clean Fuels Program. South Coast AQMD provided $1 million in Clean Fuels funding for POLA's Zero Emission Freight Shore-to-Store Project (S2S), which also received $41.1 million in funding from CARB's ZANZEFF Program for a total project cost of $82.5 million. The S2S project includes Toyota, Kenworth and Shell which are developing and demonstrating ten Kenworth zero emission Class 8 fuel cell electric trucks and two heavy-duty hydrogen stations in Wilmington and Ontario. South Coast AQMD also provided $500,000 in cost-share for POLB's Sustainable Terminals Accelerating Regional Transformation (START) Project, which also received $50 million in funding from CARB's ZANZEFF Program for a total project cost of $103 million. The START Project is developing and demonstrating 33 battery electric yard tractors, one battery electric top handler, six battery electric forklifts, 9 battery electric RTG cranes, five Class 8 battery electric yard trucks, and one electric drive tugboat at SSA Marine Terminal and Shippers Transport Express. These projects will be completed mid-2021 and should provide significant viability and performance information on battery electric and fuel cell electric technologies across multiple pieces of cargo handling equipment used by ports.

In 2019, the Clean Fuels Fund provided funding towards the "Commercialization of the Port of Long Beach Off-Road Technology" (C-PORT) Demonstration Project, which also received $5.3 million in CARB GGRF funding for a total project cost of $8.7 million. This is a follow-on to an earlier GGRF-funded project demonstrating battery electric and fuel cell electric cargo handling equipment at the Long Beach Container Terminal (LBCT) during which SSA Marine Terminal helped prove and resolve earlier issues in these technologies. The C-PORT Project will demonstrate three battery electric top handlers, one battery electric yard truck and one fuel cell yard truck to directly compare the performance of battery electric and fuel cell electric trucks in cargo handling operations. SSA Marine Terminals demonstrated two battery electric top handlers, while the LBCT demonstrated one battery electric top handler, one battery electric yard truck and one fuel cell electric yard truck in revenue service.


**Figure 7: CPORT Project at LBCT & SSA Marine at POLB**

The C-PORT Project is POLB's first demonstration of the Taylor/BYD battery electric top handlers. Taylor and BYD collaborated on design and production of the three top handlers with duty-cycle testing and UL safety certification. The battery electric top handlers have a 931-kWh battery pack and fast charge using 200 kW DC fast chargers, capable of operating for two 8-hour shifts. The top handlers will be demonstrated for a six-month period starting in February 2020. The project also features a Kalmar/TransPower battery electric yard truck with a 154-kWh battery pack, operating time of 6-21 hours, and a recharge time of less than 3 hours. The battery-electric yard truck also utilizes the 200 kW DC fast chargers installed for the battery electric top handlers. The Kalmar/TransPower battery electric yard truck started its demonstration in July 2019 and will continue to collect data for at least six months.

**Figure 8: Taylor/BYD Battery Electric Top Handler**

Lastly, the C-PORT project will demonstrate a China National Heavy-Duty Truck Group Company (CNHTC)/ Sinotruk fuel cell electric yard truck with a 56-kW fuel cell. The yard truck will be fueled by an Air Products HF-150 mobile hydrogen fueling platform with a capacity of 150 kg. Potential emission reductions for the five pieces of cargo handling equipment in the C-PORT Project are 0.69 tons/year of NOx, 0.159 tons/year of ROG, and 0.021 tons/year of PM10.

**Figure 9: Kalmar/TransPower Battery-Electric Yard Truck**

The C-PORT Project highlights some of the challenges underlying implementing zero emission technologies at the Ports for cargo handling operations. There is still a lack of standardization for heavy-duty charging infrastructure in terms of non-UL or Nationally Recognized Testing Laboratory (NRTL) approved chargers, connectors and cables. Although the CCS1 connector standard is the prevalent nationally recognized DC fast charging connector standard for North America, there are chargers that are manufactured elsewhere which come with connectors that are standard in other parts of the world, such as the GB/T connector for China or the CCS2 connector used in Europe. The non-standard chargers, connectors and cables for the battery-electric top handlers and yard truck required inspection and field certification by TUV North America to confirm compliance with relevant

**Figure 10: CNHTC/LOOP Energy Fuel Cell Yard Truck**


**Figure 11: Battery-Electric Top Handler in Service**

codes and standards and local municipal permitting requirements.

There were also some initial issues with the telematics system and failure of the power steering on the Kalmar/ TransPower battery electric yard truck that were later resolved. Additional coordination is required between Air Products and Sinotruk for the fuel cell yard truck to work with the hydrogen fueling infrastructure. Sinotruk is also arranging for a certified engineering assessment on collision testing for the hydrogen tank with a U.S. company to ensure compatibility of the tank with the fueling infrastructure. Also, there were design modifications required on the fuel cell electric yard truck to ensure the fifth wheel can operate without coming in to contact with the hydrogen fuel tank behind the cab.

Demonstration of the battery-electric yard tractors and the fuel cell yard truck will start in 2020, and the project is scheduled for completion in August 2020. Results from the cargo handling equipment and infrastructure will inform development of these technologies in the S2S and START projects.

**Continued Development of Natural Gas Engine Emissions and Efficiency Improvements**

The South Coast AQMD has been supporting rapid deployment of near-zero natural gas engines for both medium-duty and heavy-duty vehicles that have been commercialized since 2015 and supporting alternative fuel light-duty passenger vehicles since early 2000s. With nearly two decades of operational experience in the Basin, natural gas technology is well on its way towards full commercialization (achieving a Technology Readiness Level 9; see page Figure 3). However, there are ongoing concerns, such as those highlighted in the 2019 Feasibility Assessment for Drayage Trucks by Gladstein Neandross & Associates5, including the need for higher efficiency, more powerful natural gas engines.

To help advance natural gas vehicle technologies, the South Coast AQMD partnered with DOE, NREL and CEC to launch a research effort to identify ways to increase efficiencies from natural gas medium- and heavy-duty engines and vehicles. In September 2018, as part of this ongoing effort, NREL issued an RFP offering funding of approximately $37 million for projects focusing on: (1) reducing the cost of natural gas vehicles; (2) increasing vehicle efficiency; and (3) advancing new innovative medium- and heavy-duty natural gas 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.

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

One of those awards was to Cummins Inc., the largest U.S. manufacturer of medium- and heavy-duty natural gas engines. Cummins will address natural gas 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. Most heavy-duty natural gas engines, such as the Cummins ISX12N referenced as the baseline in Figure 12 below, were retrofitted from heavy-duty diesel engines rather than natural gas specific designs. The engine will be integrated on a global heavy-duty base engine platform, enabling up to 20 percent reduction in system costs. The technical targets of the project include demonstrating a ten percent improvement in cycle average and peak brake thermal efficiency over the commercially available product and maintaining 0.02 g/bhp-hr NOx capability, as shown in Figure 12 below. This project kicked off in fourth quarter 2019 and is expected to continue over a 40-month period.

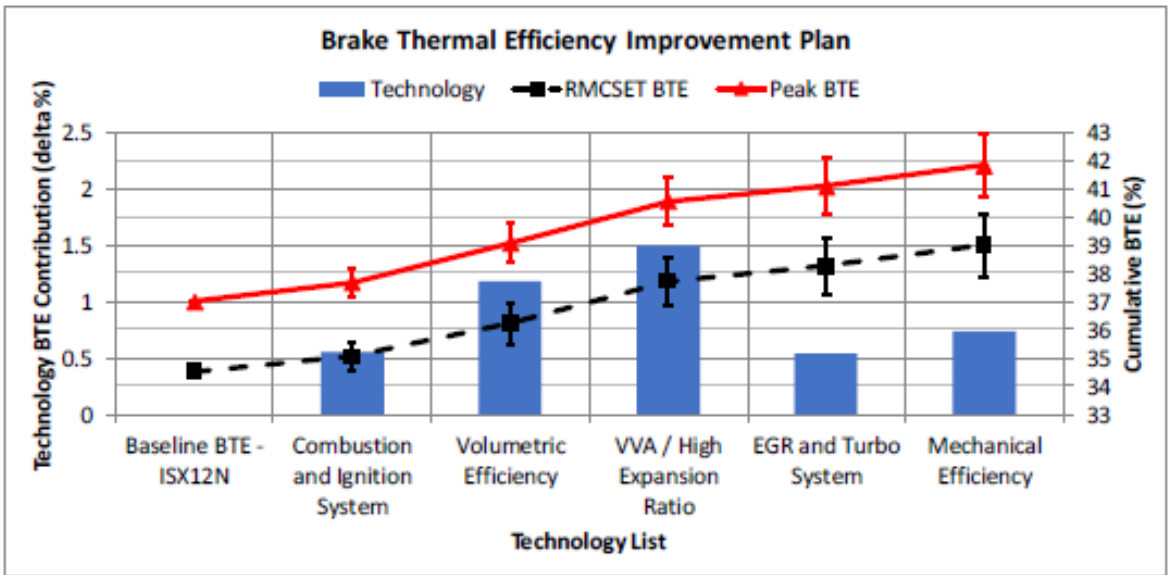


**Figure 12: Projected Heavy-Duty Natural Gas Engine Efficiency Improvement Pathways**

Two additional projects funded under the same solicitation will kick off in 2020, including development of CNG-electric hybrid systems for both medium- and heavy-duty applications. The future development will seek to increase the efficiency of the natural gas engines while maintaining 0.02 g/bhp-hr NOx capability. If successful, the projects will prove out that there are multiple technology pathways to reducing NOx while concurrently achieving reductions in fuel consumption and GHG emissions.

### Development of Fuel Cell-Gas Turbine Hybrid Technology

The University of California Irvine's Advanced Power and Energy Program (UCI's APEP) is conducting a DOE-funded study to develop solid oxide fuel cell-gas turbine (SOFC-GT) hybrid technology. The goal of the project is to dramatically reduce the water requirement for operating on natural gas in two applications - distributed generation (~10 MW) and gasified coal and biomass central power generation (~100MW). A suitable fuel cell for these applications is the SOFC which may be fueled by natural gas, biogas or hydrogen. When the SOFC-GT system is integrated into a Brayton cycle, the hybrid technology achieves a high efficiency generation of electricity.

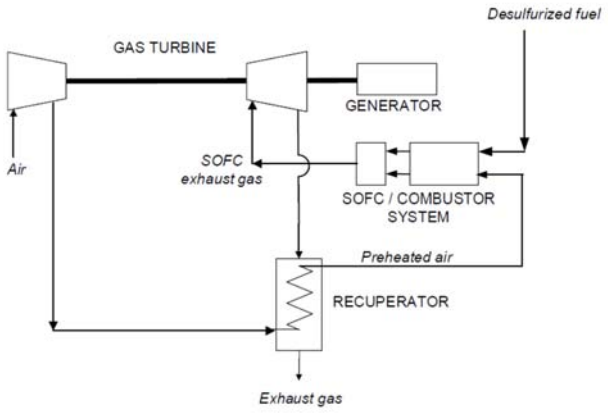


**Figure 13: SOFC integrated system with a gas turbine**

Operated on natural gas, the SOFC-GT hybrid has the potential for efficiencies approaching 75 percent. Due to the ultra-high efficiency of the SOFC-GT hybrid system, CO2 emissions are reduced significantly. UCI is interested in leveraging the DOE-funded study to expand the scope to include natural gas, biogas, mixtures of natural gas and biogas, and eventually renewable hydrogen applications in the 1-10 MW range for potential uses in off-road vehicles.

This project will develop an integration model to fully realize the potential of hybrid SOFC-GT systems in the 1-10 MW range fueled by natural gas, biogas and renewable hydrogen. The model will quantify thermal and environmental performances and economics of various alternate schemes. The 1-10 MW range is applicable for repowering locomotives with SOFC-GT power blocks, from switchers (~1MW) to long-haul locomotives (~5 MW). Similarly, ocean going vessels (OGVs) also fall into this power range. The potential for powering locomotives and OGVs powered by SOFC-GT technology will be addressed, along with the applications to the distributed generation market.

Smaller scale energy conversion devices, especially those at the distributed-scale, typically do not have the same level of emissions cleanup of equipment as larger sites, e.g., central-scale power plants. To avoid these emissions and their potential impact on air quality within the basin, it is important to understand how such devices need to be configured to take advantage of advanced technologies including fuel cells and renewable fuels. This research will directly contribute towards achieving South Coast AQMD goals, as well as achieving co-benefits to help meet GHG reduction targets in 2030 and 2050 by providing insight for the development/implementation of highly efficient and environmentally sensitive SOFC-GT energy conversion systems that complement intermittent renewable generation resources.


**Figure 14: SOFC-GT system application--Locomotives & OGVs**

## Technology Deployment and Commercialization

One function of the Clean Fuels Program is to help expedite the deployment and commercialization of zero, near-zero and low emission technologies and fuels needed to meet the requirements of the AQMP control measures. In many cases, new technologies, although considered "commercially available," require assistance to fully demonstrate the technical viability to end-users and decision-makers.

It is important to note here that South Coast AQMD's Technology Advancement Office (TAO) administers not only the Clean Fuels Program but also the Carl Moyer Program (and other significant incentive programs, such as Proposition 1B-Goods Movement and the Community Air Protection Program). These two programs produce a unique synergy, with the Carl Moyer Program providing the necessary incentives to push market penetration and commercialization of zero and near-zero emission technologies developed and demonstrated by the Clean Fuels Program. This synergy enables the South

Coast AQMD to act as a leader in both technology development and commercialization efforts targeting reduction of criteria pollutants and GHG reduction co-benefits.

This report, however, is required to detail the accomplishments and achievements of the Clean Fuels Program. Two examples of such projects launched during CY 2019 include: (1) Battery-Electric Shuttle Bus Replacement Project; and (2) Expansion of Hydrogen Fueling Station for Cars and Buses. In January 2018, U.S. EPA notified the South Coast AQMD that two awards had been approved under a FY 17 Targeted Airshed Grant solicitation in the amount of $3,184,875 to replace diesel and gasoline airport shuttle buses with zero emission battery-electric buses.

**Battery-Electric Shuttle Bus Replacement Project**

Due to projected increases in airline passenger transportation and expansion of operations at various commercial airports, significant increases in emissions of ozone precursors, toxic air contaminants and GHGs were anticipated, particularly in EJ communities adjacent to the airports. In addition to aircraft emissions, indirect airport activities, such as passenger transportation to and from the airport, are one of the major emission sources with adverse impact on air quality and public health. Airport shuttle buses include buses that transport passengers to and from car parking lots and airport terminals as well as those that transport passengers to airport car rental facilities. The emissions in this source category are expected to increase significantly with the projected increase in passenger aviation activities.

The South Coast AQMD Board has directed staff to develop proposed voluntary and regulatory measures to reduce emissions from the ports, warehouses, airports, rail yards and new development. For the region's five major commercial airports, staff will develop voluntary agreements with each airport to develop its own Clean Air Action Plan (CAAP). The CAAPs will aim to reduce emissions from non-aircraft sources such as vehicles and ground service equipment.

The electrification of these airport shuttles will provide significant benefits in emission reductions and public health for the EJ communities around the airports. Also, successful demonstration of these shuttles will prove its performance and reliability and will lead to larger-scale deployment of the technology at the airports and beyond.

**Figure 15: Phoenix Motorcars ZEUS 400 Shuttle Bus**

This project is to replace 29 diesel and gasoline airport shuttle buses with new battery-electric shuttle buses manufactured by Phoenix Motorcars, an electric vehicle manufacturer. The new electric buses are equipped with state-of-the-art electric drivetrain technology that delivers up to 100 miles range on a single charge. Combined with dual charging capability, the buses are well suited to meet the requirements of most fleets operating on a fixed route within proximity of the airport. Phoenix Motorcars is committed to providing significant cost-share and securing additional funds from CARB's Hybrid and Zero Emission Truck and Bus Voucher Incentive Project (HVIP) to cofund the shuttle bus replacement project.

The shuttle bus fleet operators, including offsite airport parking companies, airport employee shuttle service providers, hotels and rental car companies, are operating substantial numbers of buses continuously during their 24-hour operations. Electrifying these shuttle buses is an ideal starting point to the adoption of emerging technologies, as their operations are predictable over fixed routes, with

limited daily mileage eliminating range anxiety. Airport shuttle buses operate in highly congested environments and idle frequently, leading to very high fuel usage and emissions. On average, an equivalent conventional-fueled shuttle bus returns a fuel efficiency of six miles per gallon. Completely removing the emissions from the operations and by using no fuel, fleet operators can significantly improve the energy efficiency of their operations. Fleet operators will also benefit from significantly lower operational costs due to lower maintenance and fuel costs. Drivers and employees of fleet operators also directly benefit from zero emissions work environments.

The electrification of airport shuttle buses will serve as a catalyst to the adoption of zero emission electric drivetrain technologies amongst medium and heavy-duty fleets. Furthermore, the project will serve as a demonstration of the capabilities and readiness of electric shuttle buses as a commercially viable and economically beneficial alternative. In the medium to long term, the successful deployment of electric shuttle buses through this project will also serve as a model for other large airports in the U.S. to follow and significantly low exposure for disadvantaged communities typically located adjacent to airports.

**Expansion of Hydrogen Fueling Station for Cars and Buses**

The University of California Irvine (UCI) station has been in operation since January 2003, supporting research and fuel cell vehicle development. In 2007, it became the first dual-pressure station operating in the U.S. with public access for fuel cell vehicle fueling. The station has been upgraded over the years, opening as a retail station for fueling passenger cars in November 2015 and refueling buses at night, including fleet buses for the Orange County Transit Authority (OCTA). Customer demand continues to increase beyond its design throughput capacity, resulting in an urgent need for expansion of capacity and fueling positions. Shifting to liquid hydrogen deliveries will strengthen supply chains, potentially reducing the price of dispensed hydrogen.

The UCI hydrogen station expansion project provides a unique public-private partnership opportunity to enable ongoing research on a larger capacity retail hydrogen station serving retail and transit customers. UCI will expand their hydrogen fueling station from the current capacity of 180 kilograms per day (kg/day) of delivered gaseous hydrogen to more than 800 kg/day of delivered liquid hydrogen and from one to four fueling positions, with both 350 bar and 700 bar hydrogen. On-site storage will also increase, further strengthening the hydrogen supply chain, and limiting impacts to the consumers. Delivered hydrogen is expected to be at least 33 percent renewable, in compliance with SB 1505 requirements.

In addition to serving more light-duty vehicles, buses will continue to be scheduled for fueling at night to minimize impact on light-duty customers. Expansion of the station will enable UCI to increase the number of fuel cell buses serving the campus, as well as provide support, if needed, for the increased number of fuel cell buses planned for deployment by OCTA, leading to a more robust hydrogen fueling network. This station will provide an excellent example for larger station designs needed to reduce costs while expanding throughput to reach California's goals of 200 stations by 2025, and the CaFCP Vision 2030 for 1,000 stations in California to support one million vehicles.

As stations grow, continued public research is needed to evaluate multiple aspects. Fueling protocols, dispenser design and station throughput and reliability are just some examples that can be evaluated by UCI. UCI intends to report at least three years of operating data through the National Renewable Energy Laboratory.

UCI has been and continues to be instrumental in hydrogen related research for more than two decades. The National Fuel Cell Research Center (NFCRC), located at UCI, was dedicated in 1998 by DOE and CEC to: 1) accelerate the development and deployment of fuel cell technology; 2) enable the stationary and mobile fuel cell market; 3) address market hurdles; 4) convene government agencies, businesses and academia to develop effective public-private alliances, and 5) provide leadership in the preparation of educational materials and programs to help develop the national work force in fuel cell technology. The NFCRC focuses on both mobile and stationary fuel cells, the development of a hydrogen fueling infrastructure, and the interface between stationary fuel cell technology, transportation and the emerging hydrogen economy. In fact, in November 2019, to assist the NFCRC at UCI in continuing these efforts, the South Coast AQMD established an $625,000 endowment for the NFCRC to support graduate students studying emerging issues and the latest research related to air quality and climate change using funds in a special settlement fund.

**Figure 16: Existing Dispenser Installed November 2015**

UCI's station upgrade continues to push technology, design and cooperation to deploy increasing numbers of fuel cell cars and buses and further study issues related to co-locating hydrogen fueling for light-, medium- and heavy-duty vehicles and larger volume stations supported by increasing liquid hydrogen storage. This expansion also provides continued opportunity for students to experience the deployment of advanced technology.

# CLEAN FUELS PROGRAM
# 2019 Funding & Financial Summary

The South Coast AQMD 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. In order 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 5), the 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 throughout the year, the 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, 2019.

## Funding Commitments by Core Technologies

The 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, 2019, a total of 72 contracts/agreements, projects or studies that support clean fuels were executed or amended (adding dollars), as shown in Table 2 (page 32). 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 17 (page 30). This wide array of technology support represents the 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 2019 reporting period are shown below with the total projected project costs:

- South Coast AQMD Clean Fuels Fund Contribution $11,870,196
- Total Cost of Clean Fuels Projects $133,738,963

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, the fund transfer from Clean Fuels to the General Fund was handled through the annual budget process. Thus, when the Board approved the South Coast AQMD's FY 2019-20 Budget on May 3, 2019, it included $1 million from Clean Fuels recognized in TAO's budget for technical assistance, workshops, conferences, cosponsorships and outreach activities, as well as postage, supplies and miscellaneous costs; another $285,000 is transferred from the Clean Fuels Fund to Capital Outlays for alternative fuel vehicle purchases for TAO's Alternative Fuel Demonstration Program as well as supporting vehicle and energy infrastructure. Only the funds committed by December 31, 2019, are included within this report. Any portion of the Clean Fuels Funds not spent by the end of Fiscal Year 2019-20 ending June 30, 2020, will be returned to the Clean Fuels Fund.

Partially included within the South Coast AQMD contribution are supplemental sponsorship revenues from various organizations that support these technology advancement projects. This supplemental revenue for pass-through contracts executed in 2019 totaling $3,122,426 is listed within Table 3 (page 34). This $3.12 million was provided from a U.S. EPA Targeted Airshed Grant for battery-electric shuttle bus replacements.

For Clean Fuels executed and amended contracts, projects and studies in 2019, the average South Coast AQMD contribution is approximately 7 percent of the total cost of the projects, identifying that each dollar from the South Coast AQMD was leveraged with more than $14 of outside investment. The typical historical leverage amount is $4 for every $1 of South Coast AQMD Clean Fuels funds, but from 2016 to 2019 there were several significant contracts, significant both in funding and in the impact that they hopefully will make in strides toward developing and commercializing clean transportation technologies.

During 2019, the distribution of funds for South Coast AQMD executed contracts, purchases and contract amendments with additional funding for the Clean Fuels Program totaling approximately $11.9 million are shown in the figure below.

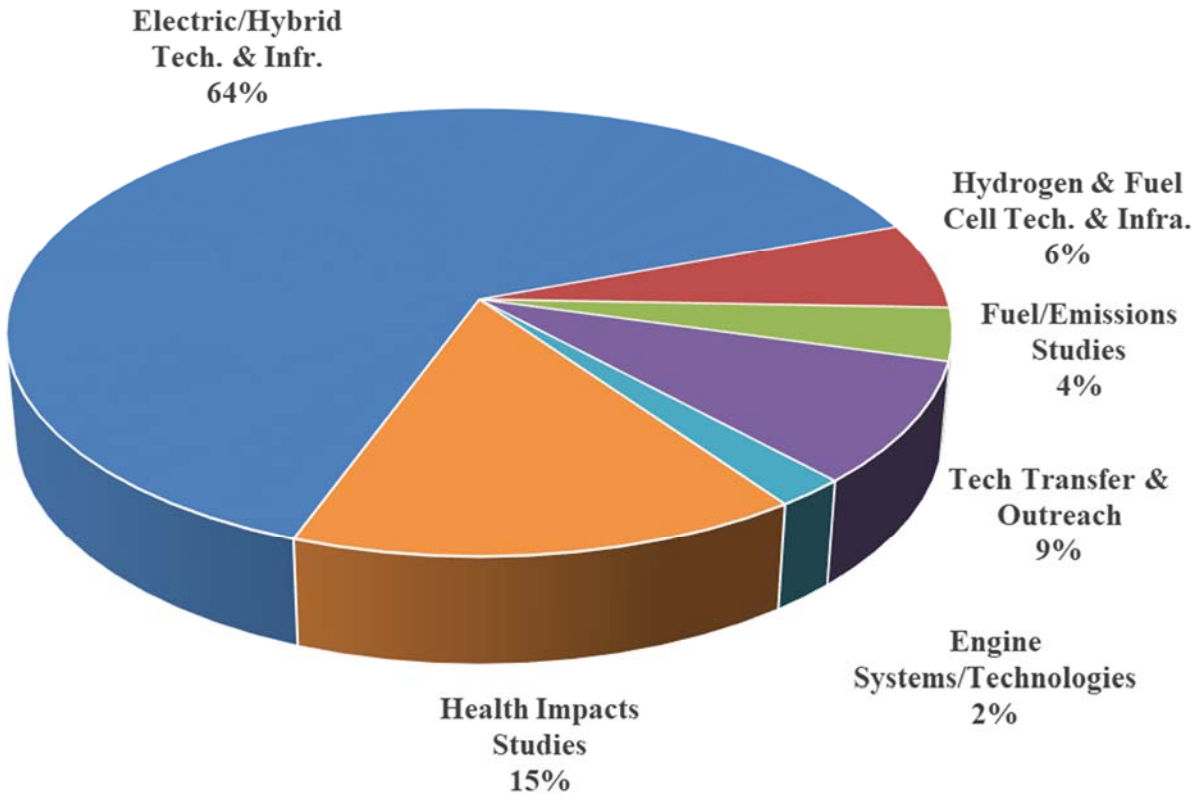


**Figure 17: Distribution of Funds for Executed Clean Fuels Projects CY 2019 ($11.9M)**

Additionally, the South Coast AQMD continued to seek funding opportunities in the 2018-2019 timeframe and was awarded an additional $19.9 million in CY 2019 for RD[3] projects. Table 4 (page 34).

As of January 1, 2020, there were 128 open Clean Fuels Fund contracts. Appendix B lists these contracts by core technology.

# Review of Audit Findings

State law requires an annual financial audit after the closing of each South Coast AQMD's fiscal year. The financial audit is performed by an independent Certified Public Accountant selected through a competitive bid process. For the fiscal year ended June 30, 2019, the firm of BCA Watson Rice, LLP, conducted the financial audit. As a result of this financial audit, a Comprehensive Annual Financial

Report (CAFR) was issued. There were no adverse internal control weaknesses with regard to South Coast AQMD financial statements, which include the Clean Fuels Program revenue and expenditures. BCA Watson Rice, LLP, gave the South Coast AQMD an "unmodified opinion," the highest obtainable. Notably, the South Coast AQMD has achieved this rating on all prior annual financial audits.

# Project Funding Detail by Core Technologies

The 72 new and continuing contracts/agreements, projects and studies that received South Coast AQMD funding in CY 2019 are summarized in Table 2 (beginning on the next page), together with the funding authorized by the South Coast AQMD and by the collaborating project partners.

## Table 2: Contracts Executed or Amended (w/$) between Jan. 1 & Dec. 31, 2019

| Contract | Contractor | Project Title | Start Term | End Term | SCAQMD $ | Project Total $ |
|---|---|---|---|---|---|---|
| **Hydrogen/Mobile Fuel Cell Technologies and Infrastructure** | | | | | | |
| 19191 | University of California Irvine | Develop Solid Oxide Fuel Cell and Gas Turbine Hybrid Technology | 06/21/19 | 06/20/20 | 200,000 | 900,000 |
| 19248 | Tustin Hyundai | Lease One 2019 Fuel Cell Hyundai Nexo for Three Years | 03/07/19 | 03/06/22 | 25,193 | 25,193 |
| 20038 | University of California Irvine | Expand Hydrogen Fueling Station for Cars and Buses | 10/18/19 | 02/17/27 | 400,000 | 1,800,000 |
| 20088 | Frontier Energy, Inc. | Participate in California Fuel Cell Partnership for Calendar Year 2019 and Provide Support for Regional Coordinator | 01/01/19 | 12/31/19 | 120,000 | 1,300,000 |
| **Engine Systems/Technologies** | | | | | | |
| 19439 | Cummins Inc. | High Efficiency Natural Gas Medium- and Heavy-Duty Engine Development and Research | 08/30/19 | 08/29/23 | 250,000 | 10,996,626 |
| **Electric/Hybrid Technologies and Infrastructure** | | | | | | |
| 18397 | Port of Long Beach | Demonstrate Zero Emission Cargo Handling Vehicles at Port of Long Beach | 01/04/19 | 05/31/20 | 350,000 | 8,688,410 |
| 19166 | Phoenix Cars LLC dba Phoenix Motorcars | Battery Electric Shuttle Bus Replacement Project | 01/31/19 | 01/30/22 | 3,122,426 | 7,311,456 |
| 19278 | Volvo Trucks North America | Demonstrate Zero Emission Trucks and EV Infrastructure through Volvo Low Impact Green Heavy Transport Solutions Project | 04/24/19 | 04/23/22 | 4,000,000 | 91,246,900 |
| 19438 | Puente Hills Hyundai | Lease Two 2019 Hyundai Kona Evs for Three Years | 06/06/19 | 06/05/22 | 61,156 | 61,156 |
| 20054 | Puente Hilly Hyundai | Lease One 2019 Hyundai Kona EV for Three Years | 08/23/19 | 08/22/22 | 29,640 | 29,640 |
| Various | Various | Disburse Donated Mercedes-Benz USA Electric Vehicle Chargers | 01/10/19 | 04/19/22 | 0 | 0 |
| Direct Pay | Clean Fuel Connection, Inc. | Installation of EV Charging Signage and One Station | 02/01/19 | 08/31/19 | 4,440 | 4,440 |
| **Fuel/Emissions Studies** | | | | | | |
| 19208 | University of California Riverside/CE-CERT | Conduct Emissions Study on Use of Alternative Diesel Blends in Off-Road Heavy-Duty Engines | 06/21/19 | 04/30/20 | 261,000 | 1,353,499 |

## Table 2: Contracts Executed or Amended (w/$) between Jan. 1 & Dec. 31, 2019 (cont'd)

| Contract | Contractor | Project Title | Start Term | End Term | SCAQMD $ | Project Total $ |
|---|---|---|---|---|---|---|
| **Fuel/Emissions Studies (cont'd)** | | | | | | |
| 19208 | University of California Riverside/CE-CERT | Conduct Emissions Study on Use of Alternative Diesel Blends in Off-Road Heavy-Duty Engines | 06/21/19 | 04/30/20 | 261,000 | 1,353,499 |
| 20058 | University of California Riverside | Evaluate Meteorological Factors and Trends Contributing to Recent Poor Air Quality in Basin | 08/23/19 | 08/23/20 | 188,798 | 188,798 |
| **Health Impacts Studies** | | | | | | |
| Fund Transfer | Various | Conduct Fifth Multiple Air Toxics Exposure Study (MATES V) | 01/01/18 | 06/30/20 | 1,815,800 | 5,486,810 |
| **Technology Assessment and Transfer/Outreach** | | | | | | |
| 12376 | University of California Riverside/CE-CERT | Technical Assistance with Alternative Fuels, Biofuels, Emissions Testing and Zero-Emissions Transportation Technology | 06/13/14 | 05/31/22 | 150,000 | 150,000 |
| 12453 | TechCompass | Technical Assistance with Alternative Fuels, Fuel Cells, Emissions Analysis and Aftertreatment Technologies | 06/21/12 | 05/31/20 | 10,000 | 10,000 |
| 17358 | AEE Solutions, LLC | Technical Assistance with Heavy-Duty Vehicle Emissions Testing, Analysis and Engine Development | 06/09/17 | 05/31/21 | 100,000 | 100,000 |
| 19078 | Clean Fuel Connection, Inc. | Technical Assistance with Alternative Fuels, EVs, Charging and Infrastructure, and Renewable Energy | 09/07/18 | 09/30/21 | 50,000 | 50,000 |
| 19227 | Gladstein, Neandross & Associates LLC | Technical Assistance with Alternative Fuels & Fueling Infrastructure, Emissions Analysis and On-Road Sources | 02/01/19 | 01/31/21 | 200,000 | 200,000 |
| 19302 | Hydrogen Ventures | Technical Assistance with Hydrogen Infrastructure and Related Projects | 04/24/19 | 04/23/21 | 50,000 | 50,000 |
| 20085 | CALSTART Inc. | Technical Assistance for Development and Demonstration of Infrastructure and Mobile Source Applications | 11/08/19 | 11/07/21 | 150,000 | 150,000 |
| Direct Pay | Prizm Imaging | Procure Outreach Equipment and Materials | 08/01/18 | 09/24/19 | 1,554 | 1,554 |
| Direct Pay | Various | Alternative Fuel Demonstration Vehicle Program Related Expenses | 02/01/19 | 09/30/19 | 3,579 | 3,579 |
| Direct Pay | Various | Cosponsor 23 Conferences, Workshops & Events plus 2 Memberships | 01/01/19 | 12/31/19 | 326,610 | 3,650,902 |
| | | | | | | **$11,870,196** |

**Table 3: Supplemental Grants/Revenue Received into the Clean Fuels Fund (31) in CY 2019**

| Revenue Agreement # | Revenue Source | Project Title | Contractor | SCAQMD Contract # | Award Total $ |
|---|---|---|---|---|---|
| #19165 | U.S. EPA Airshed Grant | Battery Electric Shuttle Bus Replacement Project | Phoenix Motorcars | #19166 | $3,184,875 |
| *Table 3 lists revenue awarded to South Coast AQMD and received into the Clean Fuels Fund (31) only if the South Coast AQMD pass-through contract was executed during the reporting CY (2019).* | | | | | **$3,184,875** |

**Table 4: Summary of Federal, State and Local Funding Awarded or Recognized in CY 2019**

| Awarding Entity or Program | Award (*) or Board Date | Purpose | Contractors | Award Total/ Fund |
|---|---|---|---|---|
| Veolia ES Technical Solutions, LLC | 03/01/19 | Install Air Filtration Systems at Schools (U.S. EPA Supplemental Environmental Project) | IQ Air North America | $161,352 Fund 75 |
| Aliso Fund | 05/03/19 | Install Air Filtration Systems at Schools (Aliso Supplemental Environmental Project) | IQ Air North America | 7,100,000 Fund 75 |
| U.S. EPA Airshed Grant | 07/12/19 | Develop and Demonstrate Battery-Electric Excavator and Wheel Loader | Volvo Technology of America, LLC | 2,100,000 Fund 31 |
| U.S. EPA Airshed Grant | 07/12/19 | Deploy Zero Emission Electric Delivery Trucks | Daimler Trucks North America | 4,177,083 Fund 31 |
| U.S. EPA Section 105 CATI Grant | 07/12/19 | Daimler Zero Emission Trucks and EV Infrastructure Project | Daimler Trucks North America | 500,000 Fund 31 |
| World Oil Corporation | 09/06/19 | Install Air Filtration Systems at Schools (U.S. EPA Supplemental Environmental Project) | IQ Air North America | 167,967 Fund 75 |
| U.S. EPA DERA Grant | 09/23/19* | Market Acceleration Program: Near-Zero Natural Gas Heavy-Duty Trucks including Trade-Down | Various Fleets/Truck Owners | 2,289,581 Fund 31 |
| SoCalGas | 10/4/19 | Development, Demonstration and Commercialization of Near-Zero Emissions Natural Gas Conversion Systems | A-1 Alternative Fuel Systems; Landi Renzo USD; and Agility Fuel Solutions | 900,000 Fund 61 |
| San Pedro Bay Ports | 11/1/19 | Clean Shipping Technology Demonstration | MAN Energy Solutions USA | 1,000,000 Fund 83 |
| Pacific Resource Recovery Services, Dean Foods Company and Tesoro Refining & Marketing Company | 12/09/19 | Install Air Filtration Systems at Schools (U.S. EPA & CARB Supplemental Environmental Projects) | IQ Air North America | 316,000 Fund 75 |
| Navistar, CNS, J&P Cycles | 12/19/19* | Install Air Filtration Systems at Schools (Navistar) and Residences (CNS, J&P) (CARB Supplemental Environmental Projects) | IQ Air North America | 1,205,300 Fund 75 |
| *Table 4 provides a comprehensive summary of revenue awarded to South Coast AQMD during the reporting CY (2019) 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.* | | | | **$19,917,283** |

# Project Summaries by Core Technologies

The following summaries describe the contracts, projects and studies executed, or amended with additional dollars, in CY 2019. They are listed in the order found in Table 2 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.

## *Hydrogen/Mobile Fuel Cell Technologies and Infrastructure*

### 19191: Develop Solid Oxide Fuel Cell and Gas Turbine Hybrid Technology

| | | |
|---|---|---|
| Contractor: University of California Irvine | South Coast AQMD Cost-Share | $ 200,000 |
| | Cosponsor | |
| | U.S. Dept. of Energy | 700,000 |
| Term: 06/21/19 – 06/20/20 | Total Cost: | $ 900,000 |

The University of California Irvine (UCI) through its Advanced Power and Energy Program is working on developing solid oxide fuel cell-gas turbine (SOFC-GT) hybrid technology. This project will develop an integration model to fully realize the potential of hybrid SOFC-GT systems in the 1-10 MW range fueled by natural gas, biogas and renewable hydrogen. The model will quantify thermal and environmental performances and economics of various alternate schemes. The 1-10 MW range is applicable for repowering locomotives with SOFC-GT power blocks, from switchers (~1MW) to long-haul locomotives (~5 MW). Similarly, ocean going vessel (OGV) power also falls into this power range. The potential for powering locomotives and OGVs with SOFC-GT technology will be addressed, along with the applications to the distributed generation market.

### 19248: Lease One 2019 Fuel Cell Hyundai Nexo for Three Years

| | | |
|---|---|---|
| Contractor: Tustin Hyundai | South Coast AQMD Cost-Share | $ 25,193 |
| Term: 03/07/2019 – 03/06/2022 | Total Cost: | $ 25,193 |

The South Coast AQMD operates several alternative fuel vehicles, including electric vehicles, fuel cell vehicles and plug-in hybrid-electric vehicles. The primary objective of having these vehicles as part of the South Coast AQMD demonstration fleet is to continue to support the use of zero emissions vehicles. The fuel cell Hyundai Nexo is the first dedicated hydrogen-powered SUV and provides the highest range of any fuel cell or electric vehicle with an EPA-estimated range of 380 miles.

### 20038: Expand Hydrogen Fueling Station for Cars and Buses

| | | |
|---|---|---|
| Contractor: University of California Irvine | South Coast AQMD Cost-Share | $ 400,000 |
| | Cosponsors | |
| | California Energy Commission | 400,000 |
| | MSRC/AB 2766 Discretionary Fund | 1,000,000 |
| Term: 10/18/19 – 02/17/27 | Total Cost: | $ 1,800,000 |

The University of California Irvine (UCI) will expand their hydrogen fueling station from the current capacity of 180 kilograms per day (kg/day) of delivered gaseous hydrogen to in excess of 800 kg/day of delivered liquid hydrogen and from one to four fueling positions, with both 350 bar and 700 bar hydrogen. Delivered hydrogen is expected to be at least 33 percent renewable, in compliance with SB 1505 requirements. In addition to serving more light-duty vehicles, buses will continue to be scheduled for fueling at night to minimize impact on light-duty customers. Expansion of the station will enable UCI to increase the number of fuel cell buses serving the campus, as well as provide support, if needed, for the increased number of fuel cell buses planned for deployment by the Orange County Transportation Authority, leading to a more robust hydrogen fueling network. Fueling protocols, dispenser design and station throughput and reliability are just some examples that can be evaluated by UCI. This expansion also provides continued opportunity for students to experience the deployment of advanced technology.

### 20088: Participate in California Fuel Cell Partnership for Calendar Year 2019 and Provide Support for Regional Coordinator

| | | |
|---|---|---|
| Contractor: Frontier Energy, Inc. | South Coast AQMD Cost-Share | $ 120,000 |
| | Cosponsors | |
| | 7 automakers, 3 public agencies, 4 industry stakeholders, 32 Full & Associate Members | 1,180,000 |
| Term: 01/01/19 – 12/31/19 | Total Cost: | 1,300,000 |

In April 1999, the California Fuel Cell Partnership (CaFCP) was formed with eight members; South Coast AQMD joined and has participated since early 2000. The CaFCP and its members are demonstrating and deploying fuel cell passenger cars, transit buses, and heavy-duty trucks with associated hydrogen fueling infrastructure in California. Since the CaFCP is a voluntary collaboration, each participant contracts with Frontier Energy Inc. (previously Bevilacqua-Knight, Inc. or BKi) for their portion of the CaFCP's administration. In 2019, South Coast AQMD contributed $70,000 for Executive membership and $50,000 to continue support for a Regional Coordinator.

## *Engine Systems/Technologies*

### 19439: High Efficiency Natural Gas Medium- and Heavy-Duty Engine Development and Research

| | | |
|---|---|---|
| Contractor: Cummins Inc. | South Coast AQMD Cost-Share | $ 250,000 |
| | Cosponsors | |
| | U.S. Dept. of Energy | 3,183,773 |
| | California Energy Commission | 566,227 |
| | Cummins Inc. | 6,996,626 |
| Term: 08/30/19 – 08/29/23 | Total Cost: | $ 10,996,626 |

The DOE, National Renewable Energy Laboratory (NREL), CEC and South Coast AQMD partnered to launch a research effort to increase efficiency of natural gas engines for medium- and heavy-duty engines and vehicles as part of a $37 million solicitation. This project is one of four projects that aligned well with South Coast AQMD priorities. Cummins Inc. will address natural gas engine emissions and efficiency improvements by developing a new natural gas specific combustion design utilizing high tumble charge motion and cooled exhaust gas recirculation (EGR). The engine will be integrated on a

global heavy-duty base engine platform in the 12- to 15-liter displacement range, enabling up to 20 percent reduction in system costs. The technical targets of the project include demonstrating a 10 percent improvement in cycle average and peak brake thermal efficiency over the commercially available product and maintaining 0.02 g/bhp-hr NOx capability with reduced aftertreatment cost. This project was kicked off in fourth quarter 2019 and expected to continue over a 40-month period.

## *Electric/Hybrid Technologies and Infrastructure*

### 18397: Demonstrate Zero Emission Cargo Handling Vehicles at Port of Long Beach

| | | |
|---|---|---|
| Contractor: Port of Long Beach | South Coast AQMD Cost-Share | $ 350,000 |
| | Cosponsors | |
| | California Air Resources Board | 6,066,000 |
| | Port of Long Beach | 1,184,530 |
| | Long Beach Container Terminal | 642,321 |
| | SSA Marine Terminal | 445,559 |
| Term: 01/04/19 – 5/31/20 | Total Cost: | $ 8,688,410 |

The Commercialization of the Port of Long Beach Off-Road Technology (C-PORT) Demonstration Project is an early recipient of a CARB Greenhouse Gas Reduction Fund (GGRF) project that demonstrates battery-electric and fuel cell electric cargo handling equipment. This includes a six-month demonstration of two Taylor/BYD battery-electric yard tractors at SSA Marine Terminal, one Taylor/BYD battery-electric yard tractor, one Kalmar/TransPower battery-electric yard truck and one China National Heavy-Duty Truck Group Company (CNHTC)/Sinotruk fuel cell electric yard truck at Long Beach Container Terminal. Demonstration of the battery electric yard truck started in July 2019 and demonstration of the battery electric top handlers and fuel cell electric yard truck will start in February 2020, with the project scheduled for completion in August 2020. Results from the cargo handling equipment and infrastructure will inform future development of these technologies at the San Pedro Bay Ports.

### 19166: Battery Electric Shuttle Bus Replacement Project

| | | |
|---|---|---|
| Contractor: Phoenix Cars LLC dba Phoenix Motorcars | South Coast AQMD Cost-Share *(received as pass-through funds)* | $ 3,122,426 |
| | Cosponsors | |
| | Phoenix Motorcars/CARB HVIP | 4,189,030 |
| Term: 01/31/19 – 01/30/22 | Total Cost: | $ 7,311,456 |

In January 2018, U.S. EPA notified the South Coast AQMD that two awards had been approved under a FY 2017 Targeted Airshed Grant solicitation to replace diesel and gasoline airport shuttle buses with zero emissions battery electric buses. This project is to replace 29 diesel and gasoline airport shuttle buses with new battery electric buses manufactured by Phoenix Motorcars. The new electric buses are equipped with state-of-the-art electric drivetrain technology that delivers up to 100 miles range on a single charge. Combined with dual charging capability, the buses are well suited to meet the requirements of most fleets operating on a fixed route within proximity of the airport. Phoenix Motorcars, an electric vehicle manufacturer, is committing significant cost-share and securing additional funds from CARB's Hybrid and Zero Emission Truck and Bus Voucher Incentive Project (HVIP) to cofund the shuttle bus replacement project. This contract includes pass-through funds

totaling $3,122,426 in FY 2017 U.S. EPA Airshed Grant revenues. Administrative funds totaling $62,449 to implement the project were also included in the Airshed Grant for a total award of $3,184,875 (see Table 3).

### 19278: Demonstrate Zero Emission Trucks and EV Infrastructure through Volvo Low Impact Green Heavy Transport Solutions Project

| | | |
|---|---|---|
| Contractor: Volvo Trucks North America | South Coast AQMD Cost-Share | $ 4,000,000 |
| | Cosponsors | |
| | California Air Resources Board | 41,591,592 |
| | Volvo Trucks North America | 45,655,308 |
| Term: 04/24/19 – 04/23/22 | Total Cost: | $ 91,246,900 |

Volvo Trucks North America and South Coast AQMD secured a CARB Zero and Near-Zero Emission Freight Facilities (ZANZEFF) grant for the Volvo Low Impact Green Heavy Transport Solutions (LIGHTS) project to demonstrate 8 pilot and 15 production Class 8 battery-electric trucks at Dependable Highway Express (DHE) in Ontario and NFI Industries in Chino, two freight handling facilities in San Bernardino County. The Volvo LIGHTS project also includes the demonstration of 29 battery electric forklifts, yard tractors and support EVs; 59 Level 2 and DC fast chargers; and production of 1.8 million MWh annually of solar. Five pilot vehicles were delivered to California in 2019 and will be driven 10,000 miles on local roads prior to being deployed at DHE and NFI in spring 2020. Volvo will be deploying their production vehicles later in 2020 and is applying for the Zero Emission Powertrain certification to allow these vehicles to become commercially available in California. For this project, pass-through funding from CARB totaling $41,591,592 was received into a special revenue fund, the GHG Reduction Projects Special Revenue Fund (67), while the South Coast AQMD provided $4,000,000 in cost-share from the Clean Fuels Fund (31).

### 19438: Lease Two 2019 Hyundai Kona EVs for Three Years

| | | |
|---|---|---|
| Contractor: Puente Hills Hyundai | South Coast AQMD Cost-Share | $ 61,156 |
| Term: 06/06/2019 – 06/05/2022 | Total Cost: | $ 61,156 |

The South Coast AQMD operates several alternative fuel vehicles, including electric vehicles, fuel cell vehicles and plug-in hybrid-electric vehicles. The primary objective of having these vehicles as part of the South Coast AQMD demonstration fleet is to continue to support the use of zero emissions vehicles. The Hyundai Kona EV is the first all-electric subcompact SUV with EPA-estimated range of 258 miles.

### 20054: Lease One 2019 Hyundai Kona EV for Three Years

| | | |
|---|---|---|
| Contractor: Puente Hills Hyundai | South Coast AQMD Cost-Share | $ 29,640 |
| Term: 08/23/2019 – 08/22/2022 | Total Cost: | $ 29,640 |

The South Coast AQMD operates several alternative fuel vehicles, including electric vehicles, fuel cell vehicles and plug-in hybrid-electric vehicles. The primary objective of having these vehicles as part of the South Coast AQMD demonstration fleet is to continue to support the use of zero emissions vehicles. The Hyundai Kona EV is the first all-electric subcompact SUV with U.S. EPA-estimated range of 258 miles.

### Various: Disburse Donated Mercedes-Benz USA Electric Vehicle Chargers

| | | |
|---|---|---|
| Contractor: Various | South Coast AQMD Cost-Share | $ 0 |
| | Cosponsor | |
| | Mercedes-Benz USA, LLC | 0 |
| Term: 01/10/19 – 04/19/22 | Total Cost: | $ 0 |

In October 2018, the South Coast AQMD accepted a donation of 977 Level 2 EV chargers offered by Mercedes-Benz USA LLC. South Coast AQMD identified residents and sites in disadvantaged communities to receive the chargers. This included rebate recipients from South Coast AQMD's Replace Your Ride Program (a scrap and trade program for low-income residents) who opted to purchase battery electric or plug-in electric vehicles to replace their older vehicle. Staff also worked with multiple utilities and local governments, including Los Angeles County and the Southern California Public Power Authority (SCPPA), to identify recipients of the donated EV chargers. In CY 2019, the South Coast AQMD executed agreements with Mercedes-Benz USA to accept the donated EV chargers, with both Los Angeles County and SCPPA to facilitate the donations, and with 21 individual residents in the Basin who were awarded one of the donated EV chargers. All of these were no-cost agreements.

### Direct Pay: Installation of EV Charging Signage and One Station

| | | |
|---|---|---|
| Contractor: Clean Fuel Connection, Inc. | South Coast AQMD Cost-Share | $ 4,440 |
| Term: 02/01/19 – 08/31/19 | Total Cost: | $ 4,440 |

Beginning in late 2015, the South Coast AQMD undertook an expansion and upgrade of the EV charging infrastructure at its headquarters in Diamond Bar. The Diamond Bar facility had 28 Level 2 chargers and 1 DC fast charger. After the expansion, the facility had 92 Level 2 charges and 1 DC fast charger for use by staff, visitors and the public as well as equipment for cost recovery and demand response capabilities. In CY 2019, staff secured Clean Fuel Connection, Inc., to install 47 directional and wayfinding EV charging signs and 10 towing signs for South Coast AQMD headquarters' EV charging network. These signs will assist EV drivers in locating the chargers, and towing signs will enable these chargers to be available to EV drivers in need of charging on a timely basis. In addition, one EV charging station was installed at Board Member Delgado's residence to support the EV assigned to her for demonstration of early commercial, long range battery electric vehicles.

## *Fuel/Emissions Studies*

### 19208: Conduct Emissions Study on Use of Alternative Diesel Blends in Off-Road Heavy-Duty Engines

| | | |
|---|---|---|
| Contractor: University of California Riverside/CE-CERT | South Coast AQMD Cost-Share | $ 261,000 |
| | Cosponsors | |
| | California Air Resources Board | 932,499 |
| | U.S. Environmental Protection Agency | 150,000 |
| | San Joaquin Valley APCD | 10,000 |
| Term: 06/21/19 – 04/30/20 | Total Cost: | $ 1,353,499 |

The South Coast AQMD regularly participates in emissions research projects with CARB. The emergence of renewable diesel and biofuels has raised the need to better understand emissions and performance effects relative to current ultra-low sulfur diesel. This study, a collaboration with CARB and the U.S. EPA, will conduct detailed emissions testing on various renewable diesel blends and biodiesel blends on heavy-duty off-road engines. The results of this study will help promote fuel standards for various blended fuels.

### 20058: Evaluate Meteorological Factors and Trends Contributing to Recent Poor Air Quality in Basin

| | | |
|---|---|---|
| Contractor: University of California Riverside | South Coast AQMD Cost-Share | $ 188,798 |
| Term: 08/23/19 – 08/23/2020 | Total Cost: | $ 188,798 |

The South Coast Air Basin (Basin) has achieved tremendous emission reductions in ozone and particulate matter (PM), particularly for fine PM or PM2.5, over the last five decades, but the region has recently experienced a leveling from the reductions and even an uptick in ozone in 2016 and 2017. The immediate question is why? Related to this is how much is related to meteorological trends versus a response to emission changes from mobile and stationary sources. The study will employ long-term records of air quality information, emissions information and detailed meteorological information (from observations and models) to separate the contribution of meteorology and climate from the effects of emission changes due to cleaner technologies and emission regulations. The study will also use satellite-derived data on trace species loadings (e.g., NO2, formaldehyde and ozone) in conjunction with modeling techniques, which include more traditional chemical transport modeling and meteorological detrending approaches, as well as "big-data" (e.g., machine learning) approaches. While there are uncertainties in the use of any one of these techniques to answering why ozone may have increased in the past couple of years, together, they should provide a much more robust understanding of the likely causes.

## *Health Impacts Studies*

### Fund Transfer: Conduct Fifth Multiple Air Toxics Exposure Study (MATES V)

| | | |
|---|---|---|
| Contractor: Various | South Coast AQMD Cost-Share | $ 1,815,800 |
| | Cosponsor | |
| | Rule 1118 Mitigation Fund (54) | 3,671,010 |
| Term: 01/01/18 – 06/30/20 | Total Cost: | $ 5,486,810 |

Since 1987, the South Coast AQMD has conducted four Multiple Air Toxics Exposure Studies (MATES) to evaluate air toxics health risks in the Basin. MATES V launched January 2018 to monitor air toxics for a one-year period, conduct air toxics modeling and quantify the health impacts. MATES V will include local-scale studies in areas near oil refineries to assess the air toxics exposures and associated health risks in these communities. The MATES V effort included a suite of advanced air monitoring techniques, including aerial and mobile measurements of air toxics. These efforts will generate detailed air toxics maps, near real-time data on emissions and better assessment of community air toxics exposure, especially in environmental justice communities. Mitigation fees collected for exceeding rule limitations of flaring operations at refineries are deposited into the 1118 Mitigation Fund (54), and those mitigation fees are used to develop air quality improvement projects. The Clean Fuels and Rule 1118 monies are being used for staffing, technical support and equipment purchases to carry out MATES V.

## *Technology Assessment and Transfer/Outreach*

### 12376: Technical Assistance with Alternative Fuels, Biofuels, Emissions Testing and Zero Emission Transportation Technologies

| | | |
|---|---|---|
| Contractor: University of California Riverside/CE-CERT | South Coast AQMD Cost-Share | $ 150,000 |
| Term: 06/13/14 – 05/31/22 | Total Cost: | $ 150,000 |

South Coast AQMD seeks to implement aggressive programs to develop and demonstrate pre-commercial technologies for zero and near-zero emission vehicles and equipment, alternative fuels and renewable energy sources. Due to constant and rapid changes in technologies and the sheer breadth of potential projects, South Coast AQMD supplements in-house technical resources with outside expertise and assistance to evaluate and implement these demonstration projects. The University of California Riverside's (UCR) College of Engineering/Center for Environmental Research and Technology (CE-CERT) is a research center at UCR dedicated to research on air quality and energy efficiency with approximately 120 investigators including 30 Ph.D. level researchers. CE-CERT will provide technical expertise to evaluate a broad range of emerging technologies in alternative and/or renewable fuels and vehicles as well as to conduct air pollution formation and control studies.

### 12453: Technical Assistance with Alternative Fuels, Fuel Cells, Emissions Analysis and Aftertreatment Technologies

| | | |
|---|---|---|
| Contractor: TechCompass | South Coast AQMD Cost-Share | $ 10,000 |
| Term: 06/21/12 – 05/31/20 | Total Cost: | $ 10,000 |

The AQMP for the Basin identifies the application of clean burning alternative fuels (e.g., natural gas, ethanol, and hydrogen), advanced vehicle technologies (e.g., fuel cells, hybrid electric and plug-in hybrid electric vehicles) and advanced stationary source pollution control technologies to meet the national ambient air quality standards. These air quality gains, however, may only be realized if programs are in place to develop, commercialize, and implement these technologies. As a result, South Coast AQMD seeks to implement aggressive programs to develop and demonstrate pre-commercial technologies. This contract is being used to leverage staff resources with specialized outside expertise. TechCompass has over 30 years of professional experience in bringing environmental, energy and alternative propulsion technologies from the laboratory to the market. This contract was originally executed in 2012 in the amount of $75,000 and was amended in 2019 to add $10,000 to continue utilizing Tech Compass' services.

### 17358: Technical Assistance with Heavy-Duty Vehicle Emissions Testing, Analysis and Engine Development

| | | |
|---|---|---|
| Contractor: AEE Solutions, LLC | South Coast AQMD Cost-Share | $ 100,000 |
| Term: 06/09/17 – 05/31/21 | Total Cost: | $ 100,000 |

Under this contract, AEE Solutions, LLC, provides technical assistance for an in-use emissions study being conducted by West Virginia University and the University of California Riverside using Clean Fuels funds. Specifically, AEE Solutions assists in the: 1) development of test vehicle selection, activity and emissions protocols, 2) recruitment of 200 heavy-duty test vehicles, 3) preparation of a technology assessment plan to identify the impact of current and near-future technology on engine performance, emissions and fuel usage, 4) identification of engine and aftertreatment issues and how to mitigate them, and 5) matching of vehicle technologies to vocations for which technology benefits can be

maximized. This level-of-effort contract was initially executed in June 2017, then amended in late 2017 for a total contract value of $100,000. Given the volume of work needed, an amendment was executed in CY 2019 adding an additional $100,000.

### 19078: Technical Assistance with Alternative Fuels, EVs, Charging and Infrastructure, and Renewable Energy

| | | |
|---|---|---|
| Contractor: Clean Fuel Connection, Inc. | South Coast AQMD Cost-Share | $ 50,000 |
| Term: 09/07/18 – 09/30/21 | Total Cost: | $ 50,000 |

The South Coast AQMD relies on expert input, consultation and support to manage various efforts conducted under the Clean Fuels Program and TAO's many incentive programs. Clean Fuel Connection, Inc., (CFCI) is providing technical assistance with alternative fuels, renewable energy and electric vehicles as well as outreach activities to promote, assess, expedite and deploy the development and demonstration of advanced, low and zero emissions mobile and stationary technologies. This contract is for technical and administrative support to enable the range of activities involved in implementing the Clean Fuels Program and associated complementary programs, as needed. In CY 2019, additional funds for this contract were allocated to fund administrative support of various incentive and rebate programs including the Lawn Mower Rebate Program, the Commercial Electric Lawn and Garden Incentive and Rebate Program, and the Replace Your Ride Program to assist potential applicants in submitting applications.

### 19227: Technical Assistance with Alternative Fuels & Fueling Infrastructure, Emissions Analysis and On-Road Sources

| | | |
|---|---|---|
| Contractor: Gladstein, Neandross & Associates LLC | South Coast AQMD Cost-Share | $ 200,000 |
| Term: 02/01/19 – 01/31/21 | Total Cost: | $ 200,000 |

This contract leverages staff resources with specialized outside expertise. Gladstein, Neandross & Associates LLC (GNA) has previously assisted South Coast AQMD with implementing a wide-array of incentive programs to deploy lower-emitting heavy-duty vehicles and advanced transportation technologies. Under this contract, GNA will provide technical expertise across a broad spectrum of emission reduction technologies, including alternative and renewable fuels and fueling infrastructure, emissions analysis and heavy-duty on-road sources on an-as-needed basis.

### 19302: Technical Assistance with Hydrogen Infrastructure and Related Projects

| | | |
|---|---|---|
| Contractor: Hydrogen Ventures | South Coast AQMD Cost-Share | $ 50,000 |
| Term: 04/24/19 – 4/23/21 | Total Cost: | $ 50,000 |

To promote, assess, expedite and deploy the development and demonstration of advanced, zero and near-zero emissions mobile and stationary technologies, South Coast AQMD relies on expert input and consultation. Hydrogen Ventures provides nearly 35 years of experience in the fields of combustion generated pollutants and their control, advanced energy technologies (including hydrogen and fuel cells) and alternative fuels, combustion modifications, secondary combustion processes and backend control focused on boilers, thermal treatment units and stationary engines. Hydrogen Venture has established relationships with numerous equipment manufacturers in the fuel cell and fuel processing industries and has worked with South Coast AQMD, CARB, CEC, DOE and U.S. EPA. Under this

contract, Hydrogen Ventures provides technical assistance and expert consultation for alternative fuels, emissions analysis and combustion technologies.

### 20085: Technical Assistance for Development and Demonstration of Infrastructure and Mobile Source Applications

| | | |
|---|---|---|
| Contractor: CALSTART Inc. | South Coast AQMD Cost-Share | $ 150,000 |
| Term: 11/08/19 – 11/07/21 | Total Cost: | $ 150,000 |

The AQMP for the Basin identifies the application of clean burning alternative fuels (e.g., natural gas, ethanol and hydrogen), advanced vehicle technologies (e.g., fuel cells, hybrid electric and plug-in hybrid electric vehicles) and advanced stationary source pollution control technologies to meet the national ambient air quality standards. These air quality gains, however, may only be realized if programs are in place to develop, commercialize and implement these technologies. As a result, South Coast AQMD seeks to implement aggressive programs to develop and demonstrate pre-commercial technologies. This contract is being used to leverage staff resources with specialized outside expertise. CALSTART Inc.is the nation's leading clean transportation industry nonprofit that successfully spurs the commercialization of advanced transportation technologies, fuels, systems and the companies that make them. CALSTART Inc. manages a wide range of national clean transportation and grant programs in close partnership with several federal, state and regional agencies that address national and international issues related to creating the next generation of jobs and reducing emissions from transportation. The Federal Transit Administration, Caltrans and CEC were CALSTART's first partners funding consortia projects over 25 years ago, which were focused on developing and demonstrating advanced transit, infrastructure and electric drive technologies that today are entering the mainstream. CALSTART has been working as an effective catalyst for the global advanced transportation technology industry for over a decade and continues to gain momentum as a unique and increasingly important "meeting point" between key public and private sector stakeholders in the industry.

### Direct Pay: Procure Outreach Equipment and Materials

| | | |
|---|---|---|
| Contractor: Prizm Imaging | South Coast AQMD Cost-Share | $ 1,554 |
| Term: 08/01/18 – 09/24/19 | Total Cost: | $ 1,554 |

South Coast AQMD's Technology Advancement Office offers funding for research, development, demonstration and deployment of transformative transportation technologies, incentive funding to accelerate fleet turnover of both on- and off-road transportation, and rebates for residential electric lawn mowers and home EV charging, among other programs. Technology assessment and outreach efforts are a small but essential part of any effective program. It is important to inform potential stakeholders and educate the public about South Coast AQMD's technology advancement efforts toward reducing pollutants and ensuring public health. Throughout the year, the South Coast AQMD participates in dozens of conferences, symposiums, workshops and events ranging in topic from technology-focused subjects to general clean air or environmental issues. Large backdrops and smaller retractable pullups are helpful in conveying information in quick bites and drawing the attention of attendees. In 2018 and 2019, the Technology Advancement Office designed images promoting various technology programs and procured one ten-foot fabric popup display and three 6-foot pullups to display these images at various events.

**Direct Pay: Alternative Fuel Demonstration Vehicle Program Related Expenses**

| | | |
|---|---|---|
| Contractor: Various | South Coast AQMD Cost-Share | $ 3,579 |
| Term: 02/01/19 – 09/30/19 | Total Cost: | $ 3,579 |

The South Coast AQMD alternative fuel vehicle demonstration program showcases new clean-fuel vehicles to public and private organizations so that potential purchasers may familiarize themselves with available low-emission technologies and to push the development of even cleaner vehicle technologies. This direct pay covers cost of service for two PHEV Via Vans and the disposition cost of one Toyota Mirai FCV vehicle.

**Various: Cosponsor 23 Conferences, Workshops and Events plus 2 Memberships**

| | | |
|---|---|---|
| Contractor: Various | South Coast AQMD Cost-Share | $ 326,610 |
| | Cosponsors | |
| | Various | 3,324,292 |
| Term: 01/01/19 – 12/31/19 | Total Cost: | $ 3,650,902 |

The South Coast AQMD regularly participates in and hosts or cosponsors conferences, workshops and miscellaneous events. In CY 2019, South Coast AQMD provided funding for 23 conferences, workshops and events and 2 memberships in key stakeholder organizations, as follows: Clean Fuels Advisory Group Retreat in January 2019; Rethink Methane in February 2019; PEMS Conference and Workshop in March 2019; ICEPAG-Microgrid Global Summit in March 2019; ACT Expo in April 2019; Asilomar Conference on Transportation & Energy in July 2019; the 29th Real World Emissions Workshop in March 2019; Clean Transportation Summit, California: 2030 in March 2019; Hydrogen and Fuel Cells for Freight Workshop in April 2019; Women in Green Forum in August 2019; Advanced Transportation Symposium & Expo-Driving Mobility 6 in June 2019; California Fuel Cell Partnership 20th Anniversary Event in October 2019; RadLaunch Program for 2019-2020; SoCal Work Truck Show in October 2019; Los Angeles National Drive Electric Week 2019 "Charge Up LA" Event in September 2019; AltCar Expo & Conference in October 2019 in Riverside and November 2019 n Santa Monica; the 30th Real World Emissions Workshop in March 2020; CalETC Los Angeles Auto Show Events in November 2019; Renewable Gas 360 Symposium in January 2020; Special Awards at the California Science Fair in April 2019; Ports Workshop @ POLA in October 2018; Hydrogen and Fuel Cell Summit in December 2018; and California Dairy Sustainability Summit in November 2018. Additionally, for 2019, two memberships were renewed for participation in the California Hydrogen Business Council, a member-based association representing a wide array of organizations that acts as a leading advocate for the hydrogen and fuel cell industry, and Veloz, a nonprofit organization comprised of high-powered, diverse board members uniquely qualified to accelerate the shift to electric vehicles through public-private collaboration, public engagement and policy education innovation.

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# CLEAN FUELS PROGRAM
# Progress and Results in 2019

## 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 heavy-duty trucks and off-road applications. Over the last several years, the focus has shifted to near-zero and zero emission technologies for medium- and heavy-duty trucks, especially those in the goods movement and freight handling industry.

Table 6 (page 52) provides a list of 32 projects and contracts completed in 2019. Summaries of the completed technical projects are included in Appendix C. Selected projects completed in 2019 which represent a range of key technologies from near-term to long-term are highlighted below: (a) Develop and Demonstrate Vehicle-to-Grid Technology on School Buses; (b) Develop and Evaluate Low NOx Diesel Engine Aftertreatment Technologies for Heavy-Duty Diesel Engines; (c) Developing and Demonstrating Renewable Fuels; and (d) Study of Real-World Electrification Options for Environmental Justice Communities.

**Develop and Demonstrate Vehicle-to-Grid Technology on School Buses**

This project was the first to demonstrate vehicle-to-grid (V2G) functionality in electric school buses. It was a follow-on to a project the South Coast AQMD had previously funded to convert diesel school buses to electric. In 2014, the South Coast AQMD and CEC awarded funding to National Strategies, LLC, a technology developer. National Strategies also provided significant matching funds toward this $3.4 million project. The V2G school bus project also included vehicle-to-building (V2B) components. The project was to retrofit and demonstrate six diesel-powered Type C school buses with electric drive and power export systems.

The V2G school bus technology is a battery-electric drive system that uses low-cost yet powerful electric motors and lithium iron phosphate batteries, along with advanced controls. The V2G school bus platform is a variant of drive system originally developed by Transportation Power Inc. (TransPower) for yard tractors that haul heavy containers at low speeds, with a gross combined vehicle weight rating exceeding 80,000 pounds. The TransPower "ElecTruck™" drive system was adapted for medium-duty Type C school buses in a retrofit conversion. Two buses were deployed at the Torrance Unified School District (TUSD) and four at the Napa Valley Unified School District (NVUSD). The South Coast AQMD's funding was specifically directed to the deployment and demonstration of the two school buses at TUSD.

The V2G school bus technology is based substantially on (1) low-cost components; (2) advanced battery management technology to maximize battery safety and operating life; (3) onboard chargers that minimize external infrastructure requirements and expenses; (4) automated-manual transmission technology which improves operating efficiency, thereby increasing range and reducing operating cost per mile; and (5) models-based controls that can be easily adapted to new components as they emerge or to other vehicles.

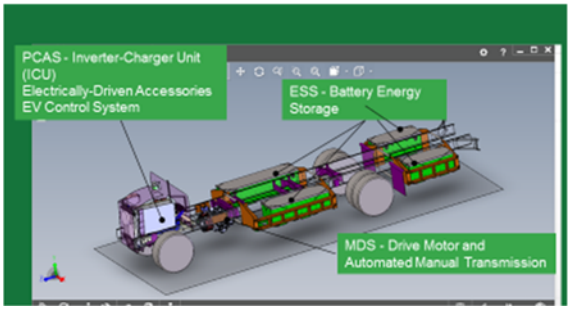


**Figure 18: Chassis Layout of EV Components**

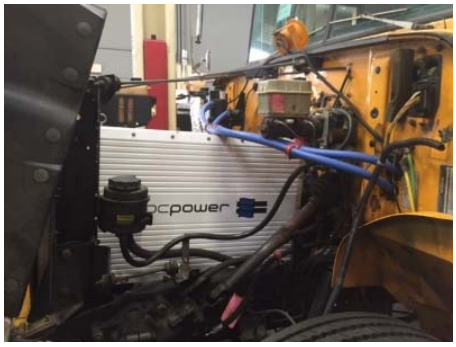

**Figure 19: Power Control & Accessory Subsystem after Installation into Bus**

The project was very successful. First, the technology met the national average range requirements of the student transportation industry, which is approximately 80 miles per day. Second, the project was able to pass all CHP requirements for school bus safety. Third, a charging infrastructure was installed which allows V2G operations and a successful interconnection agreement with the local utility was completed. Finally, and most importantly, the project delineated a clear path for EV school buses to achieve zero emission student transportation.

The V2G element of the project demonstrated that the school buses could serve as energy storage and supply peak time energy "behind the meter" of school districts and generate revenues during the long stretches of bus downtime. The energy revenue stream brings the economics of EV bus ownership within reach of school districts at a time when EV bus production costs are relatively high. The V2G electric school bus also provides frequency regulation to the grid and maintains the correct frequency throughout the grid to ensure there are no power surges and restrains the grid frequency from getting too high or too low and helps maintain it at 60HZ.

There were a few difficulties in the project, including the decision to retrofit existing 20-year-old school buses and the reluctance of the original equipment manufacturer (OEM) to provide robust support to the effort. While the age of the buses and the process of retrofitting the buses were not the only challenges, they did create significant delays and intensify reliability issues. In addition, there were significant delays on the interconnection agreement with SCE simply because this was the first project of its kind. This further delayed the project due to California Public Utility Commission rule interpretations. Ultimately, the team and SCE worked together to eventually achieve an interconnection agreement that did result in energy savings for TUSD. In conclusion, however, while the retrofit model cannot be recommended based on this project, it still resulted in value lessons learned toward technical feasibility.

From a commercialization and application perspective, this project was very successful. Prior to this project, there was not a single EV school bus in operation within California. Further, there were no school bus OEMs providing EV school buses in the market. As this project moved forward and early results were positive, the EV school bus market changed. In 2017, Blue Bird Corporation was awarded $1.9 million from the South Coast AQMD and $4.9 million from U.S. DOE to further develop components and systems for the commercialization and deployment of electric school buses. In fact, all three major school bus OEMs and a few smaller ones as well announced plans to produce EV school buses, most with some form of V2G technology. By the project conclusion, there were approximately 75 EV school buses operating in the state with a significant number on order with OEMs.

Finally, this project led to the realization that V2G technology is not a theory but a reality and resulted in the first commercially available U.S.-manufactured V2G electric school bus in all 50 states.

**Develop and Evaluate Low NOx Diesel Engine Aftertreatment Technologies for Heavy-Duty Diesel Engines**

A key measure in CARB's Mobile Source Strategy is the establishment of low NOx engine emission standards that result in a 90 percent reduction in NOx emissions compared to the emissions of today's diesel engines. This measure is critical for attaining federal health-based air quality standards for ozone in 2031 in the South Coast and San Joaquin Valley air basins, and fine PM2.5 standards in the next decade.[6]

CARB, in conjunction with Southwest Research Institute (SwRI), developed a three-stage project exploring the feasibility of technologies to achieve target tailpipe NOx levels of 0.02 g/bhp-hr from larger displacement diesel engines suitable for long-haul operations. Stage one was development and evaluation of the aftertreatment systems. The first step involved modeling and selecting the aftertreatment system. The down selected system was subsequently aged in an accelerated fashion to simulate full useful life degradation. This process simulated performance of the system at the end of useful life. However, during the aging process, an unexpected failure occurred which disturbed the experiment, resulting in the exposure of the aftertreatment system to unrepresentative conditions. CARB requested the South Coast AQMD's assistance in a joint effort to restart stage1.

SwRI, with cofunding from the South Coast AQMD and U.S. EPA's Section 105 Clean Air Technology Initiative Program, restarted Stage 1. The objective of this follow-on project was to duplicate the original CARB-funded Stage 1 effort with the goal of developing a robust aftertreatment system for the next phases of the project. SwRI developed, aged and tested a second set of catalysts to represent real-world low load and low temperature test cycles. The parts were aged for 1,000 hours and emissions testing was performed at set intervals along the Federal Test Procedure (FTP) transient cycle. The diesel demonstration platform was a 2014 Volvo MD13TC EU6 engine. The final configuration of the low NOx aftertreatment system is shown below in Figure 20 below.

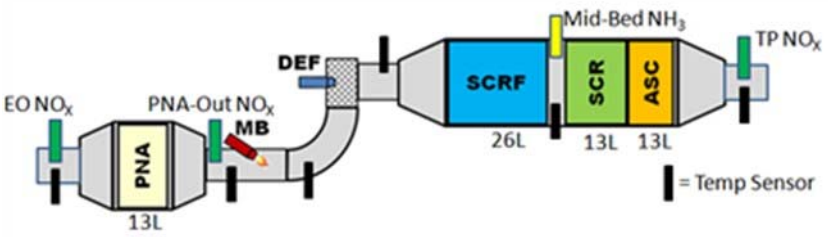


**Figure 20: Final Stage 1 Low NOX Aftertreatment System Configuration Results**

The Test Plan involved a 1,000-hour accelerated aging experiment. To gain better insight into system degradation over time, the parts were tested at two intermediate points during aging, in addition to before and after the completion of the full aging duration. Tests were conducted at the 0-hour point (following de-greening), and at 33%, 67% and 100% of the FUL aging duration of 1,000 hours. The aging was conducted using the SwRI-developed DAAAC (Diesel Accelerated Aftertreatment Aging Cycles) methodology, which accounts for both thermal and chemical aging components. However, at the end of aging, the selective catalytic reduction on filter (SCRF) contained a near maximum life duration of ash loading, prior to ash cleaning. To assess the impact of ash cleaning on the SCRF, an

[6] https://ww2.arb.ca.gov/our-work/programs/heavy-duty-low-nox/about

additional ash cleaning experiment and test were added to the Test Plan, supported with cofunding from the Manufacturers of Emission Controls Association.

The objectives of this project were proven successful. Hot-start STP performance was considerably better than what was shown in the previous Stage 1. The system maintained 99.6% NOx conversion, as compared to only 99.3% previously. This was primarily driven by the behavior of the SCRF, and it indicates that the SCRF was significantly disturbed by the upstream canning failure in the previous Stage 1. Another result from this project showed composite FTP NOx levels were 0.023 g/hp-hr after ash cleaning, as opposed to 0.034 g/hp-hr in the original Stage 1.

**Developing and Demonstrating Renewable Fuels**

Renewable natural gas (RNG) is not a fossil fuel. RNG (biogas or biomethane) is an ultra-clean and ultra-low carbon natural gas alternative. It is produced by harnessing the methane emitted when organic waste breaks down (e.g., livestock manure, forestry, food waste), allowing California to sustainably manage its vast volumes of waste products and mitigate short-lived climate pollutants.7 Nearly 16 tons of waste decomposing in California landfills could be utilized to produce energy. Methane emissions entering the atmosphere from waste is 30 times more potent than CO2 as a heat trapping gas. The conversion of waste to gas which is fully interchangeable with fossil natural gas also helps to reduce dependency on fossil fuels. Additionally, because of RNG's low carbon intensity, it qualifies for incentive funds and Low Carbon Fuel Standard credits. South Coast AQMD sees a co-benefit of lowering GHG's by converting waste to RNG and reducing air pollution when RNG is used as a fuel in low emitting engines reducing NOx emissions.

In 2017, the University of California Riverside (UCR) established a Center for Renewable Natural Gas at their College of Engineering-Center for Environmental Research (CE-CERT). This RNG Center is dedicated to researching key RNG production technologies in demonstration-scale testbeds to better address technical and other challenges, as well as systems optimization and integration needs, to lead toward commercial RNG production in California and elsewhere. The South Coast AQMD, the Southern California Gas Company and the Department of Transportation's National Center for Sustainable Transportation joined together to cost-share Phase 1 of the RNG Center effort, focusing on evaluating the RNG production potential in California and conducting a survey of thermochemical conversion technologies available for RNG production.

Anaerobic digestion (AD) is typically used to convert high moisture content biomass to RNG and thermochemical processes such as gasification and pyrolysis are typically the conversion technologies for low moisture content biomass. RNG is a low to ultra-low carbon intensity transportation fuel that can power near-zero emission heavy-duty natural gas vehicles certified to CARB's optional low-NOx emissions standard, which is 90% cleaner than current standards, and current heavy-duty diesel engines equipped with SCR systems. RNG is also a viable feedstock for renewable hydrogen (RH2) for fuel cell electric vehicles that generate zero tailpipe emissions. Its low carbon intensity comes from capturing methane, a potent short-lived climate pollutant, that would otherwise be released into the atmosphere from biomass decomposition and from displacing methane emissions and new CO2 contributions associated with fossil-based methane production and use. The following illustrates the process from RNG sources to methane conversion.

[7] https://cngvp.org/why-natural-gas/low-carbon-renewable-fuel/

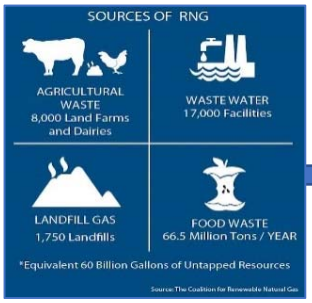


**Figure 21: RNG Sources**

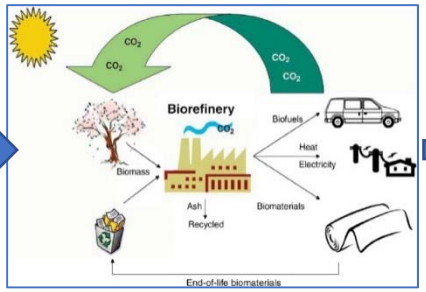


**Figure 22: RNG**

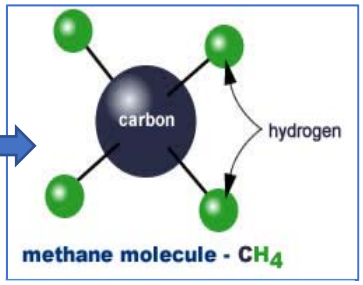


**Figure 23: RH2**

The South Coast AQMD has a long history of advancing clean fuels that are integral to the deployment of to zero, near-zero and low emission vehicles. Current funding examples include: 1) CR&R's state-of-the-art AD facility in Perris that uses the RNG it produces from the municipal solid waste it collects to power its near-zero emission heavy-duty vehicles and to inject the RNG into the SoCalGas pipeline; 2) demonstrating less commercially developed pyrolysis technology with Kore to show the viability of producing RNG and renewable hydrogen; and 3) Rialto Bioenergy Facility's commercial AD and pyrolysis project in Rialto that expects to produce significant quantities of RNG for pipeline injection and use by anchored fleets in the South Coast Air Basin.

**Figure 24: CR&R Anaerobic Digestion of MSW to RNG**

UCR's RNG Center project supported developing and demonstrating the potential for RNG production in California and particularly focused on the less commercially developed thermochemical conversion technologies to address the significant amount of available and potential low moisture-content biomass. The project also reviewed the state's clean power generation and curtailment data and the potential of power-to-gas technology to convert zero emission energy from wind and solar into a more storable form such as RNG or RH2 gas. UCR intends to continue their RNG viability efforts through the design, construction and operation of two demonstration scale plants that will form the design basis for a commercial plant along with a business plan. The final phase of the project will include a detailed engineering design of the commercial scale facility along with the permitting steps, financing details, facility construction, shakedown and operation with further technology refinement.

**Figure 25: Rialto Bioenergy Anaerobic Digestion & Pyrolysis of MWS and Biosolids to RNG**

**Figure 26: CR&R Fleet of HDVs Operating on RNG**


**Figure 27: Kore Infrastructure Pyrolysis of Biomass to RNG and RH2**

**Study of Real-World Electrification Options for Environmental Justice Communities**

Incentivizing solar technologies, electric appliances and vehicles can be an effective means to augment South Coast AQMD's existing regulations and programs to achieve further NOx and GHG reductions. Charging electric vehicles and equipment using solar panels can reduce the need for traditional fossil-based power generation for the transportation sector. But is there feasibility in promoting the greater use of solar technologies, electric appliances and vehicles for residents in environmental justice (EJ) communities, who are the most impacted by poor air quality? To answer this question, the South Coast AQMD and CEC funded a study to be conducted by the Electric Power Research Institute (EPRI) on real-world electrification options for energy services in EJ communities. EPRI also provided significant cost-share. The study considered air quality and health benefits from using solar, electric appliances and electric vehicles.

EPRI performed a statewide analysis of the economic and environmental impacts of electrification. The analysis focused on the costs and benefits of electrification technologies on residents in EJ communities. Air quality models analyzed the effects of existing electrification technologies deployed at a larger scale. Assumptions for the potential for electrification are primarily from a CEC study, "Long Term Energy Scenarios in California" (EPC 14-069, Mahone et al, 2018[8]). The Mahone study investigated potential pathways to achieve California's GHG goals. The "in-state biomass" scenario was used since it emphasized various electrification strategies. Additional assumptions were necessary since many emission sources affecting air quality are not included in GHG models. Electrification is a broad array of technologies for transitioning direct fossil fuel use to electricity. Examples of electrification technologies include batteries and motors for electrification of transportation, heat pumps for electrification of space and water heating, and technologies for industrial electrification. Air quality modeling and a health effects analysis was performed based on levels of electrification from different sources. Air quality modeling extended the current emissions inventories to the year 2050 and looked specifically at the effects of electrification on pollutant levels in future years, and health effects stemming from pollutant levels in future model years.

Precise costs for electrification are difficult to estimate due to the variety of factors that affect lifetime costs but estimates show that the costs are recovered in a few short years through air quality benefits. Monetized health benefits from reduced ozone and PM2.5 were estimated at $108 billion for the state of California in 2050, including $56 billion in benefits for this Basin. Improvements in air quality were fed into a health impacts model to calculate the monetized benefits shown in Table 5 below. Figure 28 below further illustrates this by census tract.

**Table 5: Health Benefits of Electrification in South Coast Air Basin**

| Pollutant | Avoided\| Deaths | Valuation (in billions) |
|---|---|---|
| PM2.5 | 6,242 | $54.3 |
| Ozone | 179 | $1.6 |
| **Total** | **6,421** | **$55.9** |

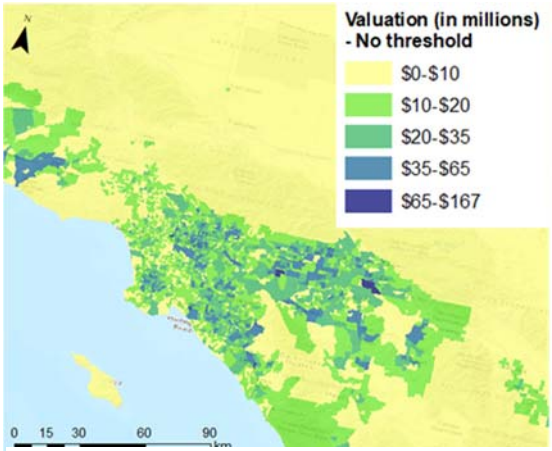


**Figure 28: Monetized Health Benefits of Electrification within the Basin by Census Tract**

For 2050, the study projects summer average maximum daily 8-hour ozone below 65 ppb in the Basin, with ozone reductions exceeding 5 ppb in most of the Basin and as much as 10 ppb. By 2050, PM2.5 is projected to be

[8] Mahone, A., Subin, Z., Kahn-Lang, J., Allen, D., Li, V. De Moor, G., Ryan, N., Price, S. Deep Decarbonization in a High Renewables Future: Updated Results from the California Pathways Model. CEC Publication Number CEC-500-2018-012.

reduced by 2 µg/m$^3$ and up to 14 2 µg/m$^3$ due to electrification. In addition, the study's modeling projects that electrification would significantly reduce mortality rates in EJ communities.

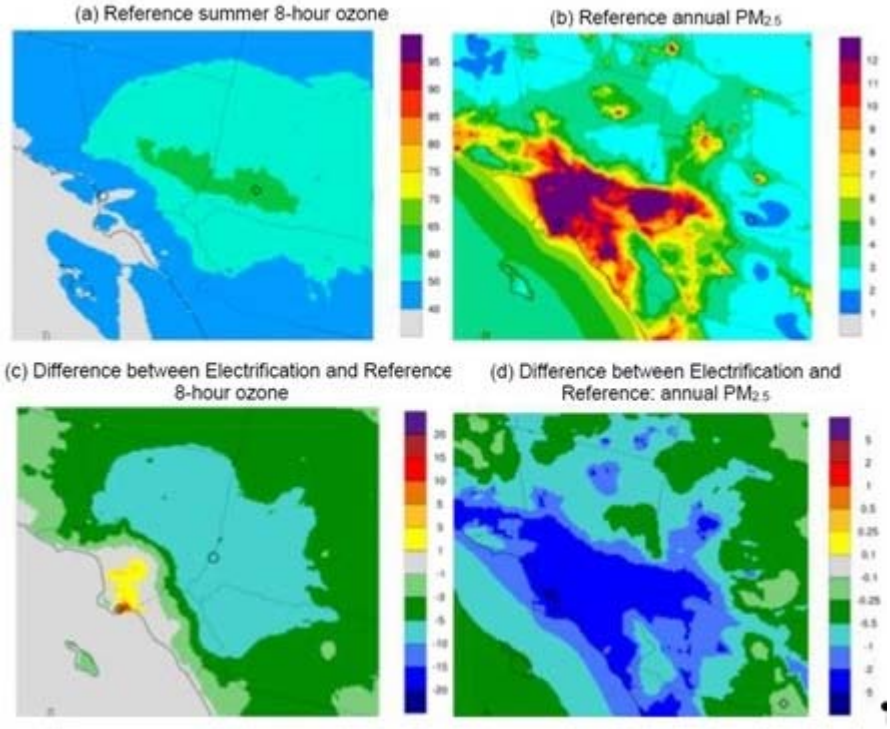


**Figure 29: Electrification Effects for Summer Max Daily Average 8-Hour Ozone and Max Annual PM2.5**

In conclusion, the study recommended that strategies be identified to provide funding for electrical infrastructure upgrades in low-income residences within EJ communities, given the high cost of retrofitting existing homes. Electrification technologies such as electric vehicles, appliances, heat pumps, and solar are commercially available but are generally more expensive than conventional options. Incentivizing these technologies for low-income residences will be necessary to cover the differential cost and enable residents in EJ communities to experience the benefits of electrification technologies.

Studies looking at the benefits of electrification such as the EPRI study support other research showing air quality and health benefits from electrification. These support policies in California, such as SB 100, requiring 60 percent renewable energy by 2030 and 100 percent renewable energy by 2045, and CEC's new Building Energy Efficiency Standards requiring solar PV systems for new home construction starting in January 1, 2020, and Net Energy Metering allowing consumers with solar to receive credit for electricity produced and fed into the grid.

In response to these developments, in 2019 the South Coast AQMD prepared a white paper on solar technologies, which recommends a shift towards electrification of residential appliances to achieve additional NOx and GHG reductions. The solar white paper proposed several measures and technologies to be undertaken as part of a new Solar Initiative being proposed for deployment of solar technologies in EJ communities. The South Coast AQMD has also developed a Net Emissions Analysis Tool (NEAT), which evaluates what the costs and NOx and GHG emission benefits will be to switch to all electric residential appliances (i.e., water and space heaters, clothes dryers, and cooktops and ovens). The new Solar Initiative will be considered by the Board in 2020.

## Table 6: Projects Completed between January 1 & December 31, 2019

| Contract | Contractor | Project Title | Date |
|---|---|---|---|
| **Hydrogen/Mobile Fuel Cell Technologies and Infrastructure** | | | |
| 19213 | Frontier Energy Inc. | Participate in California Fuel Cell Partnership for CY 2018 & Provide Support for Regional Coordinator | Jul-2019 |
| 20088 | Frontier Energy Inc. | Participate in California Fuel Cell Partnership for CY 2019 & Provide Support for Regional Coordinator | Dec-2019 |
| ***Electric/Hybrid Technologies and Infrastructure*** | | | |
| 08063 | Quantum Fuel Systems LLC | Develop & Demonstrate 20 Plug-In Hybrid Electric Vehicles | Jan-2019 |
| 13058 | Capstone Turbine Corporation | Develop Microturbine Series Hybrid System for Class 7 Heavy-Duty Vehicle Applications | Dec-2019 |
| 14222 | Odyne Systems, LLC | Develop & Demonstrate Plug-In Hybrid Electric Retrofit System for Class 6 to 8 Trucks | Aug-2019 |
| 14256 | National Strategies LLC | Develop & Demonstrate Vehicle-to-Grid Technology | Jan-2019 |
| 16227† | Selman Chevrolet Company | Lease One 2016 Chevrolet Volt Extended-Range Electric Vehicle for Three Years | Jan-2019 |
| 18072 | Electric Power Research Institute | Study Electrification Options of Energy Services for EJ Communities and Non-Attainment Areas | Jun-2019 |
| ***Fueling Infrastructure and Deployment (NG/RNG)*** | | | |
| 14219 | City of West Covina | Upgrade CNG Station at City Yard | Aug-2019 |
| 16076 | Coachella Valley Association of Governments | Purchase & Deploy One Heavy-Duty CNG Paratransit Vehicle | Nov-2019 |
| 16333 | Ontario CNG Station, Inc | Implement Alternative Fuel Station Expansion | Nov-2019 |
| 17349 | University of California Riverside/CE-CERT | Establish Renewable Natural Gas Center | Feb-2019 |
| ***Fuel/Emissions Studies*** | | | |
| 15607 | University of California Riverside/CE-CERT | Innovative Transportation System Solutions for NOx Reductions in Heavy-Duty Fleets | Jan-2019 |
| 15636 | University of California Riverside/CE-CERT | Evaluate PEV Utilization through Advanced Charging Strategies in a Smart Grid System | Dec-2019 |
| 17331 | University of California Riverside/CE-CERT | Conduct In-Use PM Emissions Study for Gasoline Direct Injection Vehicles | Jul-2019 |
| ***Emissions Control Technologies*** | | | |
| 17367 | Southwest Research Institute | Develop & Evaluate Aftertreatment Systems for Large Displacement Diesel Engines | Jun-2019 |

**Table 6: Projects Completed between January 1 & December 31, 2019 (cont'd)**

| Contract | Contractor | Project Title | Date |
|---|---|---|---|
| **Technology Assessment and Transfer/Outreach** | | | |
| 18019† | Ricardo Inc. | Technical Assistance with Heavy-Duty Vehicle Emissions Testing, Analysis and Engine Development and Applications | Aug-2019 |
| 19160† | Coordinating Research Council, Inc. | Copsonsor 2019 Mobile Source Air Toxics Workshop on 2/4-6/19 | Feb-2019 |
| 19232† | Gladstein, Neandross & Associates | Cosponsor Rethink Methane 2019 on 2/26-27/2019 | Feb-2019 |
| 19233† | University of California Riverside | Cosponsor the 2019 Portable Emissions Measurements Systems Conference & Workshop | Apr-2019 |
| 19234† | University of California Irvine | Cosponsor ICEPAG 2019 | Sep-2019 |
| 19249† | Gladstein, Neandross & Associates | Cosponsor ACT Expo 2019 | May-2019 |
| 19264† | University of California Davis-Institute of Transportation Studies | Cosponsor the Asilomar 2019 Conference on Transportation & Energy | Aug-2019 |
| 19271† | Coordinating Research Council, Inc. | Cosponsor the 29th Real World Emissions Workshop | Apr-2019 |
| 19293† | CALSTART Inc. | Cosponsor 2019 Clean Transportation Summit, California: 2030 | Apr-2019 |
| 19348† | California Hydrogen Business Council | Cosponsor Hydrogen and Fuel Cells for Freight Workshop on 4/23/19 | May-2019 |
| 19377† | Three Squares Inc. | Cosponsor the 2019 Women in Green Forum | Nov-2019 |
| 19431† | Sustain SoCal | Cosponsor the 2019 Advanced Transportation Symposium & Expo – Driving Mobility 6 | Jul-2019 |
| 20036† | Frontier Energy, Inc. | Cosponsor the California Fuel Cell Partnership 20th Anniversary Event | Nov-2019 |
| 20053† | Motor Trend Group, LLC | Cosponsor the 2019 SoCal Work Truck Show | Nov-2019 |
| 20055† | Plug In America | Cosponsor the Los Angeles National Drive Electric Week 2019 Event "ChargeUp LA" | Sep-2019 |
| 20069† | Platia Productions | Cosponsor AltCar 10/16/19 in Riverside & 11/2/19 in Santa Monica | Nov-2019 |
| 20099† | California Electric Transportation Coalition | Cosponsor the CalETC 2019 Los Angeles Auto Show Events | Dec-2019 |

†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.

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# CLEAN FUELS PROGRAM
# 2020 Plan Update

In 1988, SB 2297 (Rosenthal) was signed into law (Chapter 1546) establishing the South Coast AQMD's Clean Fuels Program and reaffirming the existence of the Technology Advancement Program (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 technology applications 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 state-of-the-art technologies, new research areas and data.

Every year, the South Coast AQMD re-evaluates the Clean Fuels Program to develop a Plan Update based on a reassessment of the technology progress and direction of the South Coast AQMD's Board. This Plan Update for CY 2020 targets several projects to help achieve near-term emission reductions needed for the South Coast to meet health-based federal air quality standards.

## Overall Strategy

The overall strategy of the TAO's Clean Fuels Program is based, in large part, on emissions reduction technology needs identified through the AQMP process and the South Coast AQMD Board's directives to protect the health of the approximately 18 million residents (nearly half the population of California) in the South Coast Air Basin (Basin). The AQMP, which is updated approximately every four years, is the long-term regional "blueprint" that relies on fair-share emission reductions from all jurisdictional levels (e.g., federal, state and local). The 2016 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).

The emission reductions and control measures in the 2016 AQMP rely on commercial adoption of a mix of currently available technologies as well as the expedited development and commercialization of lower-emitting mobile and stationary advanced technologies in the Basin to achieve air quality standards. The 2016 AQMP identifies a 45 percent reduction in NOx required by 2023 and an additional 55 percent reduction by 203 to achieve ozone standards of 80 ppb and 75 ppb, respectively. The majority of these NOx reductions must come from mobile sources, both on- and off-road. Notably, the South Coast AQMD is currently only one of two regions in the nation designated as an extreme nonattainment area (the other region is San Joaquin Valley). Furthermore, in April 2019, the South Coast AQMD requested a voluntary re-classification from U.S. EPA of the 1997 8-hour federal standard ozone for Coachella Valley to "extreme" status. Hotter summer months and the threat of climate change in the region have presented challenges that require additional time to reach attainment.

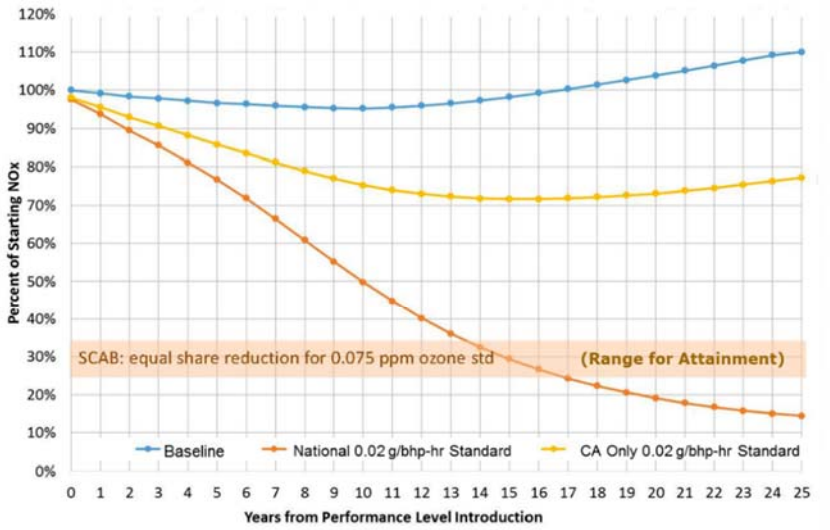
While current state efforts in developing regulations for on- and off-road vehicles and equipment are expected to reduce NOx emissions significantly, they will not be sufficient to meet the South Coast AQMD needs, especially in terms of timing. Nonetheless, for the first time, the 2016 AQMP identified a means to achieving the federal ambient standards through regulations and incentives for near-zero and zero emission technologies that are commercial or nearing commercialization. This strategy, however, requires a significantly lower state and national heavy-duty truck engine emissions standard with the earliest feasible implementation date, significant additional financial resources, and accelerated fleet turnover on a massive scale.

On June 3, 2016, in light of the need for a more stringent national heavy-duty truck engine emissions standard to achieve mobile source emission reductions, the South Coast AQMD petitioned the U.S. EPA to initiate rulemaking for a lower NOx national standard for heavy-duty engines. A national 50 state standard (as opposed to a California standard) for on-road heavy-duty vehicles is estimated to result in NOx emission reductions from this source category from 70 to 90 percent in 14 to 25 years, respectively. While CARB has adopted more stringent in-use fleet rules which require older trucks and buses to upgrade to newer, cleaner engines meeting the 2010 standard of 0.2 g/bhp-hr by 2023, CARB estimates that 60 percent of total heavy-duty vehicle miles traveled in the South Coast Air Basin are from vehicles purchased outside of California. This points to the need for a more stringent federal as well as state standard for on-road heavy-duty vehicles.

Given that the Basin must attain the 75-ppb ozone NAAQS by 2031, a new on-road heavy-duty engine NOx emission standard is critical given the time needed for OEMs to develop and produce compliant vehicles, and for national fleet turnover to occur.

Figure 30 shows the difference in NOx reductions from on-road heavy-duty trucks under three scenarios: baseline (no change in the low NOx standard) in blue, a low NOx standard adopted only in California in yellow, and lastly, a federal low NOx standard in orange.

The U.S. EPA has since acknowledged a need for additional NOx reductions through a harmonized and comprehensive national NOx reduction program for heavy-duty on-highway engines and vehicles. On November 13, 2018, U.S. EPA announced the Cleaner Truck Initiative, and on January 6, 2020, they issued an Advance Notice of Proposed Rule to reduce NOx emissions from on-road heavy-duty trucks starting as early as model year 2026. However, CARB forged ahead, announcing its own Low NOx Omnibus rule, which may be before the CARB Board as early as Spring 2020, proposing a lower NOx standard starting model year 2024. Although both announcements are welcome news, the timing is too late to help the South Coast AQMD meet its 2023 federal attainment deadline. So, despite progress, commercialization and deployment of near-zero engines are still needed.




**Source:** Presentation by Mr. Cory Palmer, ARB at the Symposium on California's Development of its Phase 2 Greenhouse Gas Emission Standards for On-Road Heavy-Duty Vehicles (April 22, 2015)

**Figure 30: NOx Reduction Comparison: No New Regulations vs Low NOx Standard in California only vs National Standard**

The findings from the MATES IV[9] study (May 2015), which included local scale studies near large sources such as ports and freeways, reinforced the importance of the need for transformative transportation technologies, especially near the goods movement corridor to reduce NOx emissions. In

[9] http://www.aqmd.gov/docs/default-source/air-quality/air-toxic-studies/mates-iv/mates-iv-final-draft-report-4-1-15.pdf?sfvrsn=7

mid-2017, South Coast AQMD initiated MATES V 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. The MATES V report is expected to be finalized by the end of 2020. In the meantime, U.S. EPA approved the use of the CARB EMFAC 2017 model for on-road vehicles for use in the State Implementation Plan and transportation conformity analyses, which assesses emissions from on-road vehicles including cars, trucks and buses. The off-road model, which assesses emissions from off-road vehicles such as yard tractors, top handlers, and rubber tire gantry cranes, is being replaced by category specific methods and inventory models being developed for specific regulatory support projects.

A key strategy of the Clean Fuels Program, which allows significant leveraging of the 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 $340 million toward projects exceeding $1.5 billion. In 1998, the 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 the technologies developed and demonstrated by the Clean Fuels Program. This synergy enables the South Coast AQMD to act as a leader in both technology development and commercialization efforts targeting reduction of criteria pollutants. Since the Carl Moyer Program began more than 20 years, the South Coast AQMD has implemented other incentive programs (i.e., Proposition 1B-Goods Movement, Community Air Protection Program and Voucher Incentive Program, to name a few), currently with cumulative funding of $250 million annually. With the success of this process, the 2016 AQMP also included control measures to develop indirect source regulations and strengthen the fleet rules that can take advantage of incentives provided, as a method of compliance to further accelerate emission reductions.

Despite several current California incentive programs to help implement cleaner technologies, however, even with some additional financial resources recently identified to offset the higher procurement costs of emerging clean technologies (i.e., Volkswagen Environmental Mitigation Trust which allocated $423 million to California), significant additional resources are still needed for the scale necessary to achieve the national ambient air quality standards for this region.

As technologies move towards commercialization, such as battery electric trucks, the Clean Fuels Program has been able to partner with large original equipment manufacturers (OEMs), such as Daimler and Volvo, in order to eventually deploy these vehicles in large numbers. These partnerships with the OEMs 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 eventually into customers' hands. The OEMs have the resources and abilities to design, engineer, test, manufacture, market, distribute and service quality products under brand names that are trusted. To obtain the emission reductions needed to meet federal and state ambient air quality standards, large numbers of advanced technology clean-fueled vehicles must be deployed across our region and state.

Figure 31 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 South Coast AQMD's 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 to achieve emission reduction benefits in the near term as well as over long term.


**Figure 31: Technology Readiness Level Stages**

While the state continues to focus their attention on climate change (GHG reductions), the South Coast AQMD remains committed to achieving NOx reductions. Fortunately, many of the technologies that address the Basin's needed NOx reductions align with the state's GHG reduction efforts. In fact, the U.S. EPA noted that in 2016 the transportation sector contributed 28 percent of overall GHG emissions. Given this, and other recent state and federal announcements, the South Coast AQMD is confident it can successfully partner on state and federally funded projects that promise NOx and GHG co-benefits.

# Program and Funding Scope

This 2020 Plan Update includes projects to research, develop, demonstrate and advance deployment ($RD^3$) a variety of technologies, from near-term to long-term, that are intended to address the following challenges:

1) implementation of new and changing 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 by including accelerated development of technologies getting ready for commercialization and deploying commercially ready technologies; and
3) continued development of near-term cost-effective approaches and long-term technology development.

The overall scope of projects in the 2020 Plan Update needs to remain sufficiently flexible to address new challenges and measures that are identified in the 2016 AQMP, consider dynamically evolving technologies, and consider new research and data. The latter might include findings from MATES V and revised emission inventories in EMFAC 2017.

Within the core technology areas defined later in this section, project objectives range from near term to long term. The South Coast AQMD 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 the Clean Fuels Program's projects is described below, from near term to long term.

- *Deployment* or technology *commercialization* efforts focus on increasing the utilization of clean technologies in conventional applications, promising immediate and growing emission reduction benefits. These are expected to result in commercially available products as early as 2021, including obtaining required certifications from CARB and U.S. EPA. It is often difficult to transition users to non-traditional technologies or fuels due to higher incremental costs or required changes to user behaviors, even if such the technologies or fuels offer significant benefits. As a result, in addition to government's role to reduce risk by funding technology development and testing, it is also necessary to support and offset incremental costs through incentives to accelerate the transition and use of cleaner technologies. The increased use and

proliferation of these cleaner technologies often depends on initial support and funding as well as efforts to increase stakeholder confidence that these technologies are real, cost-effective in the long term and viable.

- Technologies ready to begin field *demonstration* in 2020 are expected to result in commercially available products in the 2023-2025 timeframe, and technologies being demonstrated generally are in the process of being certified by CARB and U.S. EPA. 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 the technologies. Field demonstrations provide real-world evidence of performance to allay any concerns by early adopters.
- Finally, successful technology *development* projects are expected to begin during 2020 with duration of 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. Thus, development projects identified in this plan may result in technologies ready for commercial introduction as soon as 2021-2025. Projects may involve the development of emerging technologies that are considered longer term and higher risk, but with significant emission reductions potential. Commercial introduction of such long-term technologies would not be expected until 2026 or later.

# Core Technologies

The following technologies have been identified as having the greatest potential to enable the emission reductions needed to achieve 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 2020 due to funding limitations, and the focus will remain on control measures identified in the 2016 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 is significant opportunity for South Coast AQMD to leverage its funds with other funding agencies to expedite the demonstration and eventual implementation of cleaner alternative technologies in the Basin. A concerted effort is continually made to form public private partnerships to leverage Clean Fuels funds.

Several of the core technologies discussed below are synergistic. For example, a heavy-duty 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 operating on an alternative fuel as a range extender. Elements of the core hybrid electric system 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, AB 617, signed by the Governor in mid-2017, will implement actions designated in Community Emission Reduction Plans (CERPs) by five AB 617 communities within the South Coast region, and additional flexibility will be needed to develop new strategies and technologies for those disproportionately affected communities.

The following nine core technology areas are listed by current South Coast AQMD priorities based on the goals for 2020.

### *Hydrogen/Mobile Fuel Cell Technologies and Infrastructure*

The South Coast AQMD supports hydrogen infrastructure and fuel cell technologies as one option in the technology portfolio. It is dedicated to assisting federal and state government programs to deploy light-, medium-, and heavy-duty fuel cell vehicles by supporting the required hydrogen fueling infrastructure.

Calendar Years 2015-2019 were a critical timeframe for the introduction of hydrogen fueling infrastructure. In 2014, Hyundai introduced the Tucson FCV for lease. In 2015, Toyota commercialized the Mirai, the first FCV available to consumers for purchase. In December 2016, Honda started delivering its 2017 Honda Clarity FCV. Other commercially available FCVs include the Audi H-Tron Quattro, Chevrolet Colorado ZH2, Hyundai Nexo, Mercedes-Benz GLC F-Cell and Nissan X-Trail. 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 for light-duty vehicles are still needed. Changes to CARB's Low Carbon Fuel Standard (LCFS) regulation to provide credit for low carbon fuel capacity in addition to throughput should enable station operators to remain solvent during the early years until vehicle numbers ramp up. Lastly, a deliberate and coordinated effort is necessary to ensure that light-duty retail hydrogen stations are developed with design flexibility to address specific location limitations, robust hydrogen supply, and refueling reliability matching those of existing gasoline and diesel fueling stations. The current network of hydrogen fueling stations to support the current number of light-duty FCVs on the road is insufficient, and supply of hydrogen and additional hydrogen production continue to be challenges that need to be addressed.

In 2018, Former Governor Brown issued Executive Order (EO) B-48-18. Among other provisions, the order sets an additional hydrogen station network development target of 200 stations by 2025. Meeting this new ambitious target clearly requires accelerated effort on the part of the State to ensure its achievement. The EO additionally sets a target for 5 million ZEVs by 2030; FCVs are expected to comprise a significant portion of this future ZEV fleet. In September 2019, Governor Newsom issued EO N-19-19 on Climate Change, which directs CARB to push OEMs to produce even more clean vehicles, and to find ways for more Californians, including residents in disadvantaged communities, to purchase these vehicles on the new and used markets. CARB is tasked with developing new grant criteria for clean vehicle programs to encourage OEMs to produce clean, affordable cars and propose new strategies to increase demand in the primary and secondary markets for ZEVs. Finally, CARB is taking steps to strengthen existing or adopt new regulations to achieve GHG reductions within the transportation sector.

Fuel cells can play a role in medium- and heavy-duty applications where battery recharge time is insufficient to meet fleet operational requirements. The CaFCP's 2030 Vision[10] released in July 2018 provides a broader framework for the earlier Medium- and Heavy-Duty 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.

As part of the $83 million Shore-to-Store project, for which the Clean Fuels Program committed $1 million, Toyota and Kenworth will deploy 10 Class 8 fuel cell trucks and Equilon (Shell) will build two large capacity hydrogen fueling stations in Wilmington and Ontario. Kenworth will leverage the development on the fuel cell truck demonstrated in South Coast AQMD's ZECT 2 project and integrate Toyota's fuel cells into the Kenworth trucks. These fuel cell trucks will be deployed at fleets including

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

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. In 2019, Toyota displayed a second prototype Class 8 fuel cell truck at the Port of Long Beach, including plans for a new 1,000 kg/day heavy-duty hydrogen fueling station using hydrogen produced by a new tri-generation fuel cell.

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. As part of the $46 million Fuel Cell Electric Bus Commercialization Consortium project, for which the Clean Fuels fund contributed $1 million, the Center for Transportation and Environment (CTE) partnered with New Flyer, Trillium, and Orange County Transportation Authority (OCTA) to deploy 10 40-foot New Flyer XHE40 fuel cell transit buses and install a liquid storage hydrogen station capable of fueling up to 50 fuel cell transit buses at OCTA. This project also deployed 10 fuel cell transit buses and a hydrogen station upgrade at Alameda-Contra Costa Transit District (AC Transit). The transit buses were delivered in December 2019 and liquid hydrogen station was completed in January 2020.

The 2020 Plan Update identifies key opportunities while clearly leading the way for pre-commercial demonstrations of OEM vehicles. Future projects may include the following:

- continued development and demonstration of distributed hydrogen production and fueling stations, including energy stations with electricity and 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 and demonstration of cross-cutting fuel cell applications (e.g. plug-in hybrid fuel cell vehicles);
- 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 fuel cell vehicles in controlled fleet applications in the Basin;
- 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 investing as well as critical assessments of market risks to guide and protect this investment;
- coordination with fuel cell vehicle OEMs to develop an understanding of their progress in overcoming barriers to economically competitive fuel cell vehicles and develop realistic scenarios for large scale introduction; and
- repurpose of 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.

### *Engine Systems/Technologies*

To achieve the emissions reductions required for the Basin, internal combustion engines (ICEs) used in the heavy-duty sector will require emissions that are 90 percent lower than the 2010 standards as outlined in CARB's proposed Heavy-Duty On-Road "Omnibus" Low NOx regulation and EPA's Advance Notice of Proposed Rule. In 2016, commercialization of the Cummins 8.9 liter (8.9L) natural gas engine achieving 90 percent below the existing federal standard was a game changer. The 8.9L engine works well in refuse and other vocational trucks as well as transit and school buses. In 2017, Cummins Westport Inc., with South Coast AQMD and other project partners, also achieved certification of the 12L natural gas engine. The 12L engine in Class 8 drayage trucks and 60-foot articulated transit buses is a further game changer. CARB and U.S. EPA certified both engines at 0.02 g/bhp-hr for NOx. For smaller and long-haul trucks that cannot utilize the 8.9L and 12L near-zero emission engines, the 2020 Plan Update includes potential projects to develop, demonstrate and certify

natural gas engines in the 6-8L and larger 13-15L displacement range. Although no near-zero emission diesel technology is commercially available today, South Coast AQMD has been working closely with CARB and others on defining technology pathways via several projects, including the Ultra-Low Emissions Diesel Engine Program at Southwest Research Institute (SwRI), opposed piston engine development with Achates Power Inc., and Thermal Management using Cycle Deactivation Project with West Virginia University. These demonstration projects, although not yet complete, show that near-zero emission diesel technologies are feasible via advanced engine and aftertreatment or optimized engine design and calibration. The Plan Update continues to incorporate pursuit of cleaner engines for the heavy-duty sector. Future projects will support the development, demonstration and certification of engines that can achieve these massive emission reductions using an optimized systems approach. In December 2018, South Coast AQMD participated in the Natural Gas Engine & Vehicle R&D Source Review Panel meeting in Sacramento to review, discuss and prioritize several natural gas engine and vehicle technology projects that increase efficiencies using advanced engines or hybrid drive trains.

Heavy-duty hybrid vehicles have historically been optimized for fuel economy, new generation hybrid powertrains could be co-optimized for both criteria emissions and fuel economy that could better meet the air quality goals of the Basin. CARB announced their new proposal to allow medium-duty and heavy-duty hybrid powertrain certification procedures in CARB's proposed Heavy-Duty On-Road "Omnibus" Low NOx regulation. The new hybrid powertrain test procedures will properly credit for the fuel and emission benefits of hybrid vehicles and allow the entire hybrid system to certify to potentially lower engine standard on traditional engine dynamometers. South Coast AQMD have made initial contact with several OEMs to develop next generation heavy-duty hybrid powertrains to a lower NOx standard. These next generation hybrid powertrains provide another potential pathway for reducing NOx emissions in the near term.

The 2020 Plan includes potential projects that the South Coast AQMD might participate in with federal and state agencies towards these efforts. Specifically, these projects are expected to target the following:

- development of ultra-low emissions and improved higher efficiency natural gas engines for heavy-duty vehicles and high horsepower applications projects that move these technologies to a higher technology readiness level and eventual commercialization;
- continued development and demonstration of gaseous- and liquid-fueled, advanced fuels or alternative fuel medium-duty and heavy-duty engines and vehicles;
- development and demonstration of CNG hybrid vehicle technology;
- development and demonstration of diesel hybrid vehicle technology;
- development and demonstration of alternative fuel engines for off-road applications;
- evaluation of alternative engine systems such as hydraulic plug-in hybrid vehicles;
- development and demonstration of engine systems that employ advanced engine design features, cylinder deactivation, improved exhaust or recirculation systems, and aftertreatment devices; and
- development of low load and cold start technologies for hybrids and diesels where high-level emissions occur.

CARB and U.S. EPA's recent initiation to create national low NOx standard for on-highway heavy-duty engines will further motivate manufacturers to develop lower-NOx emitting technologies s expected to result in greater NOx emission reductions than a California only low NOx standard for on-road heavy-duty engines.

### *Electric/Hybrid Technologies and Infrastructure*

In an effort to meet federal standards for PM2.5 and ozone, a primary focus must be on zero and near-zero emission technologies. A key strategy to achieve these goals is the wide-scale electrification of transportation technologies. With that in mind, the South Coast AQMD supports projects to address the concerns regarding cost, battery lifetime, travel range, charging infrastructure and OEM commitment.

Integrated transportation systems can encourage further emission reduction by matching EVs (zero emission, zero start-up emission, all electric range) to typical consumer demands for mobility and by linking them to transit. Additionally, the impact of fast charging on battery life and infrastructure costs needs to be better understood. This is especially important when every month roughly 36,000[11] new plug-in vehicles are sold or leased in the U.S. This number will increase significantly with the introduction of vehicles with 200-plus mile range, such as the Chevy Bolt, launched in December 2016, the Tesla Model 3 which came out in mid-2017, and Hyundai Kona, Nissan Leaf and more to come in 2020.

The development and deployment of zero emission goods movement technologies remains one of the top priorities for the South Coast AQMD to support a balanced and sustainable growth in the port complex. The South Coast AQMD continues to work with our regional partners, in particular the Ports of Los Angeles and Long Beach, the Southern California Association of Governments (SCAG) and Los Angeles County Metropolitan Transportation Authority (Metro) to identify technologies that could be beneficial to all stakeholders. Specific technologies include zero emission trucks (battery and/or fuel cell), or plug-in hybrid powertrains, near-zero emission locomotives (e.g., 90% below Tier 4), electric locomotives using battery electric tender cars and catenary systems, and linear synchronous motors for locomotives and 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 Port of Los Angeles's Sustainable City Plan corroborates this effort, setting a goal of 15 percent of zero emission goods movement trips by 2025 and 35 percent by 2035. More recently, the Clean Air Action Plan 2017 Update adopted by Ports of Los Angeles and Long Beach calls for zero emissions cargo handling equipment by 2030 and zero emissions drayage trucks by 2035, respectively.

An example of a project in this core technology is one the South Coast AQMD is providing $500,000 from the Clean Fuels Fund to cost-share with the Port of Long Beach. The Sustainable Terminals Accelerating Regional Transformation (START) Project will develop and demonstrate 102 near-zero and zero emission vehicles, vessels, cargo handling equipment, and charging infrastructure, across an intermodal freight network at the Ports of Long Beach, Oakland and Stockton, in partnership with three California air districts. A total of 33 battery electric yard tractors, one battery electric top handler, 9 battery electric RTG cranes, five Class 8 battery electric trucks, and one electric drive tugboat will be demonstrated at the Port of Long Beach.

Continued technology advancements in light-duty infrastructure have facilitated the development of corresponding codes and standards for medium- and heavy-duty infrastructure. Additional traction may be gained in this area with the City of Los Angeles' Zero Emissions 2028 Roadmap in preparation for the 2028 summer Olympics in Los Angeles, which sets a goal of an additional 25 percent reduction in GHGs and air pollution beyond current commitments through accelerating transportation electrification. Additionally, SCE's Charge Ready Transport Program includes funding for medium- and heavy-duty vehicles and infrastructure.

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

- demonstration of battery electric and fuel cell electric technologies for cargo handling and container transport operations, e.g., heavy-duty battery electric or plug-in electric drayage trucks with all electric range;

[11] https://insideevs.com/december-2018-u-s-ev-sales-recap/?utm_source=feedburner&utm_medium=email&utm_campaign=Feed%3A+InsideEvs+%28InsideEVs%29

- demonstration of medium-duty battery electric and fuel cell electric vehicles in package delivery operations, e.g., battery electric walk-in vans with fuel cell or CNG range extender;
- development and demonstration of electric off-road vehicles; e.g. battery electric off-road construction equipment;
- development and demonstration of CNG hybrid vehicle technology;
- development and demonstration of diesel hybrid vehicle technology;
- development of hybrid vehicles and technologies for off-road vehicles;
- demonstration of niche application battery and fuel cell electric medium- and heavy-duty vehicles, including school and transit buses 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 by operating in zero emission mode 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 heavy-duty trucks;
- demonstration and installation of infrastructure to support battery electric and fuel cell electric vehicle light-, medium- and heavy-duty 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);
- development of higher density battery technologies for use in heavy-duty vehicles;
- repurpose 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;
- development of a methodology to increase understanding of the capability to accept fast-charging and the resultant life cycle and demonstration of the effects of fast-charging on battery life and vehicle performance; and
- deployment of infrastructure corresponding to codes and standards specific to light-, medium- and heavy-duty vehicles, including standardized connectors, fuel quality, communication protocols, and open standards and demand response protocols for EV chargers to communicate across charging networks.

### *Fueling Infrastructure and Deployment (Natural Gas/Renewable Fuels)*

Significant demonstration and commercialization efforts funded by the Clean Fuels Program as well as other local, state and federal agencies are underway to: 1) support the upgrade and buildup of public and private infrastructure projects, 2) expand the network of public-access and fleet fueling stations based on the population of existing and anticipated vehicles, and 3) put in place infrastructure that will ultimately be needed to accommodate transportation fuels with very low gaseous emissions.

Compressed and liquefied natural gas (CNG and LNG) refueling stations are being positioned to support both public and private fleet applications. Upgrades and expansions are also needed to refurbish or increase capacity for some of the stations installed five or more years ago as well as standardize fueling station design, especially to ensure growth of alternative fuels throughout the Basin and beyond. There is also growing interest for partial or complete transition to renewable natural gas delivered through existing natural gas pipelines. Funding has been provided at key refueling points for light-, medium- and heavy-duty natural gas vehicle users traveling from the local ports, along I-15 and The

Greater Interstate Clean Transportation Corridor (ICTC) Network. SB 350 (De León) further established a target to double the energy efficiency in electricity and natural gas end uses by 2030.

Some of the projects expected to be developed and cofunded for infrastructure development are:

- development and demonstration of renewable natural gas as a vehicle fuel from renewable feedstocks and biowaste;
- development and demonstration of advanced, cost effective methods for manufacturing synthesis gas for conversion to renewable natural gas;
- enhancement of safety and emissions reductions from natural gas refueling equipment;
- expansion of fuel infrastructure, fueling stations, and equipment; and
- expansion of infrastructure connected with existing fleets, public transit, and transportation corridors, including demonstration and deployment of closed loop systems for dispensing and storage.

### *Stationary Clean Fuel Technologies*

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. For example, a recent demonstration project funded in part by the South Coast AQMD at a local sanitation district consisted of 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 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.

SCR has been used as aftertreatment for combustion equipment for NOx reduction. 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. An ongoing demonstration project funded in part by the South Coast AQMD 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 SCR NOx emissions or lower. 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.

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 potentially stranded renewable electricity stored as hydrogen fuel. 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 the evaluation of these technologies.

Projects conducted under this category may include:

- development and demonstration of reliable, low emission stationary technologies (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; and
- vehicle-to-grid or vehicle-to-building, or other stationary energy demonstration projects to develop sustainable, low emission energy storage alternatives.

The development, demonstration, deployment and commercialization of advanced stationary clean fuel technologies will support control measures in the 2016 AQMP in that they reduce emissions of NOx and VOCs from traditional combustion sources by replacement or retrofits with zero and near-zero emission technologies.

### *Health Impacts, Fuel and Emissions Studies*

The monitoring of pollutants in the Basin is extremely important, especially when linked to (1) a particular sector of the emissions inventory (to identify the responsible source or technology) and/or (2) exposure to pollution (to assess potential health risks). In fact, studies indicate that ultrafine particulate matter (PM) can produce irreversible damage to children's lungs. This information highlights the need for further emission and health studies to identify emissions from high polluting sectors as well as the health effects 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 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. 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. In 2015, South Coast AQMD funded studies to further investigate the toxicological potential of emissions, 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. 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 the 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 natural gas and diesel heavy-duty vehicles. 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. Preliminary results suggest real-world emissions vary greatly between applications and fuel types. In 2019, CARB announced their latest proposal to the next lower level NOx standard, particularly highlighting the need to address the gap between certification values and in-use emissions. The new regulation included a new low-load cycle, new in-use emissions testing metric, and new concept to assess compliance across the entire vehicle population via onboard emission sensors. The real-world emissions study could help stakeholders better understand the impacts of emissions in real time to a specific geographic area.

In recent years, there has also been an increased interest at the state and federal level on the use of alternative fuels to reduce petroleum oil dependency, GHG emissions and air pollution. In order to sustain and increase biofuel utilization, it is essential to identify feedstocks that can be processed in a more efficient, cost-effective and sustainable manner. More recently, the power-to-gas concept has renewed interest in hydrogen-fossil fuel blends where the emissions impact on latest ICE technologies needs to be reassessed. Moreover, based on higher average summer temperatures noted over the past few years, there is interest on how the higher temperatures impact ozone formation. In line with this, a project 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 being developed under AB 617, as well as other programs targeting benefits to residents in disadvantaged communities.

Some areas of focus include:

- demonstration of remote sensing technologies to target different high emission applications and sources;
- studies to identify the health risks associated with ultrafine and ambient particulate matter including their composition to characterize their toxicity and determine specific combustion sources;
- in-use emission studies using biofuels, including renewable diesel, to evaluate in-use emission composition;
- in-use emission studies to determine the impact of new technologies, in particular EVs on local air quality as well as the benefit of telematics on emission reduction strategies;
- 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 hydrogen-fossil fuel blends on latest technology engines; and
- evaluation of the impact of higher ambient temperatures on emissions of primary and secondary air pollutants.

### *Emissions Control Technologies*

Although engine technology and engine systems research are required to reduce the emissions at the combustion source, dual fuel technologies and post-combustion cleanup mp0ethods are also needed to address currently installed on-road and off-road technologies. Existing diesel emissions can be greatly reduced with introduction of natural gas into the engine or via aftertreatment controls such as PM traps and catalysts, as well as lowering the sulfur content or using additives with diesel fuel. Gas-to-Liquid (GTL) fuels, formed from natural gas or other hydrocarbons rather than petroleum feedstock and emulsified diesel, provide low emission fuels for use in diesel engines. As emissions from engines become lower and lower, the lubricant contributions to VOC and PM emissions become increasingly important. Recently, onboard emissions sensors have been identified by CARB and other agencies as a new 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, to enable advanced concepts like Geofencing, Eco-routing, and more. The most promising of these technologies will be considered for funding, specifically:

- evaluation and demonstration of new emerging liquid fuels, including alternative and renewable diesel and GTL fuels;
- development and demonstration of renewable-diesel engines and advanced aftertreatment technologies for mobile applications (including heated dosing technologies, close coupled, catalysts, heated catalysts and other advanced selective catalytic reduction systems) as well as non-thermal regen technology;
- development and demonstration of low-VOC and PM lubricants for diesel and natural gas engines;
- develop, evaluate, and demonstrate onboard sensor-based emissions monitoring methodology; and
- develop, evaluate, and demonstrate cloud-based emissions and energy management system

### *Technology Assessment and Transfer/Outreach*

Since the value of the Clean Fuels Program depends on the deployment and adoption of the demonstrated technologies, outreach and technology transfer efforts are essential to its success. This core area encompasses assessment of advanced technologies, including retaining outside technical assistance as needed, efforts to expedite the implementation of low emission and clean fuel technologies, coordination of these activities with other organizations and information dissemination to educate end users of these technologies. Technology transfer efforts include supporting various clean

fuel vehicle incentive programs, cosponsoring technology-related conferences, workshops and other events, and disseminating information on advanced technologies to various audiences (i.e., residents in disadvantaged communities, local governments, funding agencies, technical audiences).

## Target Allocations to Core Technology Areas

The figure below presents the potential allocation of available funding, based on South Coast AQMD projected program costs of $16.1 million for all potential projects. The expected actual project expenditures for 2020 will be less than the total South Coast AQMD projected program cost since not all projects will materialize. The 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. Specific contract awards throughout 2020 will be based on this proposed allocation, the quality of proposals received and evaluation of projects against standardized criteria and ultimately South Coast AQMD Board approval.

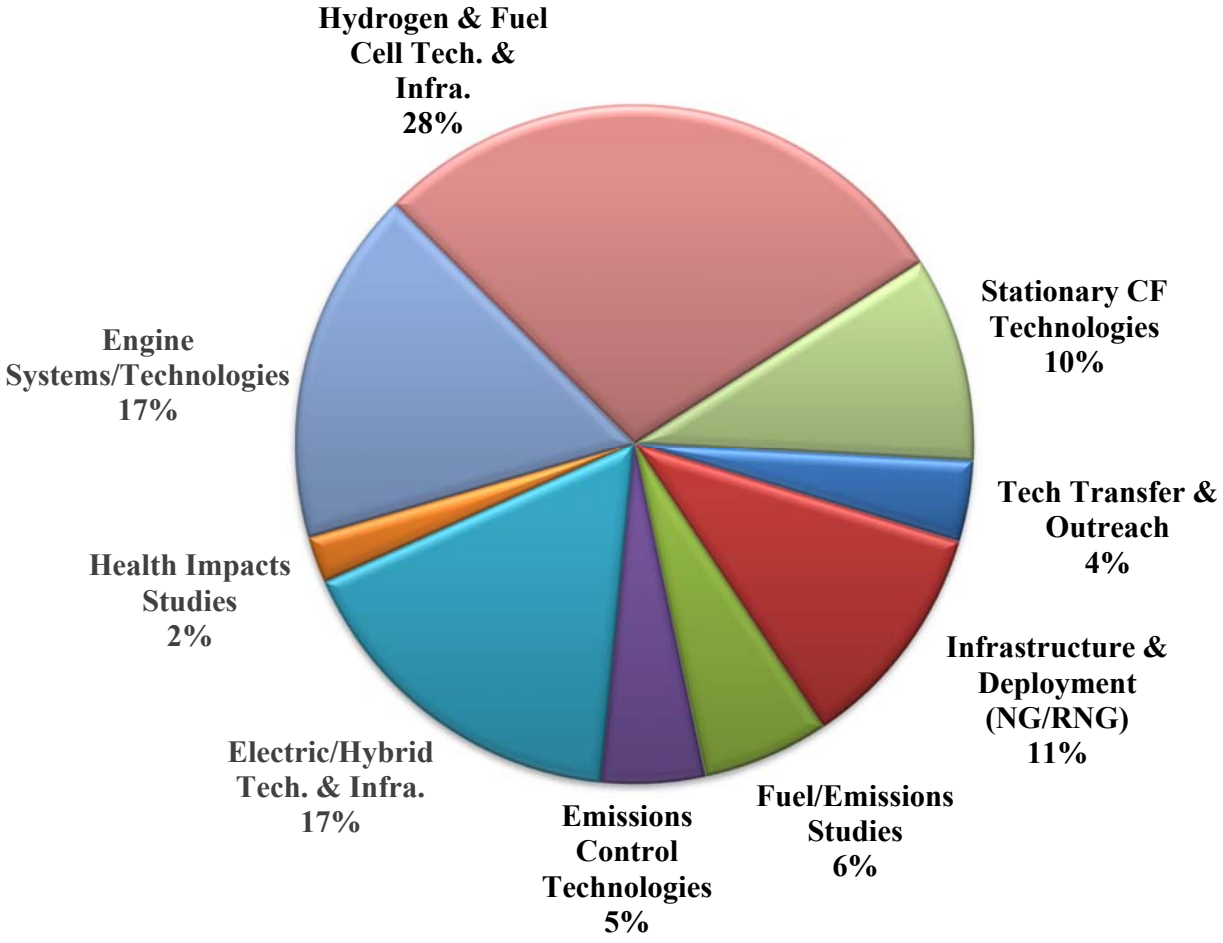



**Figure 32: Projected Cost Distribution for Potential South Coast AQMD Projects in 2020 ($16.1M)**

# CLEAN FUELS PROGRAM
# Program Plan Update for 2020

This section presents the Clean Fuels Program Plan Update for 2020. 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 be funded by revenue sources other than the Clean Fuels Program, specifically related to VOC and incentive projects.

Table 7 (page 71) summarizes potential projects for 2020 as well as the distribution of South Coast AQMD costs in some areas as compared to 2019. The funding allocation continues the focus on development and demonstration of zero and near-zero emission technologies including infrastructure to support these vehicles. For the 2020 Draft Plan, the same four funding categories remain at the top but with reduced funding for electric/hybrid technologies in light of large electric/hybrid projects recently funded and with additional funding to Stationary Clean Fuel Technologies and Emissions Control Technologies for planned projects in 2020, including:

- Heavy-duty zero emission fuel cell trucks and infrastructure;
- Onboard sensor development for emissions monitoring and improved efficiency;
- Microgrid demonstrations to support zero emission infrastructure;
- Electric school bus and fleet charging demonstrations;
- Heavy-duty diesel truck replacements with near-zero emissions natural gas trucks; and
- Fuel and emissions studies, such as conducting airborne measurements and analysis of NOx emissions and assessing emissions impacts of hydrogen-natural gas fuel blends on near-zero emissions heavy-duty natural gas engines.

As in prior years, the funding allocations again align well with the South Coast AQMD's FY 2019-20 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 perform the projects, participating host sites and fleets, and securing sufficient cost-sharing to complete the project, and other necessary factors. Recommendations to the South Coast AQMD Governing Board will include descriptions of the technologies to be demonstrated and their applications, proposed scope of work of the project and capabilities of the selected contractor(s) and project team, in addition to the expected costs and benefits of the projects as required by H&SC 40448.5.1.(a)(1). Based on communications with all of the organizations specified in H&SC 40448.5.1.(a)(2) and review of their programs, the 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 7 (page 71).

**Proposed Project:** A descriptive title and a designation for future reference.

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

**Expected Total Cost:** The estimated total project cost including the South Coast AQMD cost-share and the 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:** A brief summary of the proposed technology to be developed and demonstrated, including the expected vehicles, equipment, fuels, or processes that could benefit.

**Potential Air Quality Benefits:** A brief discussion of the expected benefits of the proposed project, including the expected contribution towards meeting the goals of the 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, the true benefits will be seen over a longer term, as a successfully demonstrated technology is eventually commercialized and implemented on a wide scale.

## Table 7: Summary of Potential Projects for 2020

| Proposed Project | Expected SCAQMD Cost $ | Expected Total Cost $ |
|---|---|---|
| **Hydrogen/Mobile Fuel Cell Technologies and Infrastructure** | | |
| Develop and Demonstrate Hydrogen Research to Support Innovative Technology Solutions for Fueling Fuel Cell Vehicles | 88,150 | 760,000 |
| Develop and Demonstrate Hydrogen Production and Fueling Stations | 1,763,000 | 6,000,000 |
| Develop and Demonstrate Medium- and Heavy-Duty Fuel Cell Vehicles | 2,644,500 | 12,000,000 |
| Demonstrate Light-Duty Fuel Cell Vehicles | 88,150 | 100,000 |
| Subtotal | $4,583,800 | $18,860,000 |
| **Engine Systems/Technologies** | | |
| Develop and Demonstrate Advanced Gaseous- and Liquid-Fueled Medium- and Heavy-Duty Engines & Vehicle Technologies to Achieve Ultra-Low Emissions | 2,203,750 | 12,500,000 |
| Develop and Demonstrate Alternative Fuel and Clean Conventional Fueled Light-Duty Vehicles | 176,300 | 1,000,000 |
| Develop and Demonstrate Low Load and Cold-Start Technologies | 176,300 | 1,000,000 |
| Develop and Demonstrate Low Emissions Locomotive Technologies | 176,300 | 1,000,000 |
| Subtotal | $2,732,650 | $15,500,000 |
| **Electric/Hybrid Technologies and Infrastructure** | | |
| Develop and Demonstrate Medium- and Heavy-Duty On-Road and Off-Road Battery Electric and Hybrid Technologies | 2,203,750 | 12,500,000 |
| Develop and Demonstrate Electric Charging Infrastructure | 220,375 | 1,250,000 |
| Demonstrate Alternative Energy Storage | 176,300 | 1,500,000 |
| Demonstrate Light-Duty Battery Electric and Plug-In Hybrid Vehicles | 100,000 | 100,000 |
| Subtotal | $2,700,425 | $15,350,000 |
| **Fueling Infrastructure and Deployment (Natural Gas/Renewable Fuels)** | | |
| Demonstrate Near-Zero Emission Natural Gas Vehicles in Various Applications | 440,750 | 2,000,000 |
| Develop, Maintain and Expand Natural Gas Infrastructure | 440,750 | 2,000,000 |
| Demonstrate Renewable Transportation Fuel Manufacturing and Distribution Technologies | 881,500 | 10,000,000 |
| Subtotal | $1,763,000 | $14,000,000 |
| **Stationary Clean Fuel Technologies** | | |
| Develop and Demonstrate Microgrids with Photovoltaic/Fuel Cell/Battery Storage/EV Chargers and Energy Management | 1,322,250 | 6,000,000 |
| Develop and Demonstrate Renewables-Based Energy Generation Alternatives | 264,450 | 1,000,000 |
| Subtotal | $1,586,700 | $7,000,000 |

**Table 7: Summary of Potential Projects for 2020 (cont'd)**

| Proposed Project | Expected SCAQMD Cost $ | Expected Total Cost $ |
|---|---|---|
| **Fuel/Emissions Studies** | | |
| Conduct In-Use Emissions Studies for Advanced Technology Vehicle Demonstrations | 308,525 | 850,000 |
| Conduct Emissions Studies on Biofuels, Alternative Fuels and Other Related Environmental Impacts | 440,750 | 1,500,000 |
| Identify and Demonstrate In-Use Fleet Emissions Reduction Technologies and Opportunities | 220,375 | 1,000,000 |
| Subtotal | $969,650 | $3,350,000 |
| **Emissions Control Technologies** | | |
| Develop and Demonstrate Advanced Aftertreatment Technologies | 176,300 | 2,000,000 |
| Develop and Demonstrate Advanced Aftertreatment Catalyst Heating Technologies | 220,375 | 1,000,000 |
| Develop Methodology and Evaluate and Demonstrate Onboard Sensors for On-Road Heavy-Duty Vehicles | 220,375 | 1,100,000 |
| Demonstrate On-Road Technologies in Off-Road and Retrofit Applications | 176,300 | 800,000 |
| Subtotal | $793,350 | $4,900,000 |
| **Health Impacts Studies** | | |
| Evaluate Ultrafine Particle Health Effects | 88,150 | 1,000,000 |
| Conduct Monitoring to Assess Environmental Impacts | 132,225 | 500,000 |
| Assess Sources and Health Impacts of Particulate Matter | 132,225 | 300,000 |
| Subtotal | $352,600 | $1,800,000 |
| **Technology Assessment/Transfer and Outreach** | | |
| Assess and Support Advanced Technologies and Disseminate Information | 352,600 | 800,000 |
| Support Implementation of Various Clean Fuels Vehicle Incentive Programs | 264,450 | 400,000 |
| Subtotal | $617,050 | $1,200,000 |
| **TOTALS FOR POTENTIAL PROJECTS** | **$16,099,225** | **$81,960,000** |

# Technical Summaries of Potential Projects

## Hydrogen/Mobile Fuel Cell Technologies and Infrastructure

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

**Expected South Coast AQMD Cost:** $88,150

**Expected Total Cost:** $760,000

**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 light-duty 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.

The California Hydrogen Infrastructure Research Consortium focuses on top research needs and priorities to address near-term problems in order to support California's continued leadership in innovative hydrogen technology solutions needed for fueling FCVs. 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. Currently, funded tasks include data collection from operational stations, component failure fix verification (i.e., nozzle freeze lock), analysis of data to optimize new fueling methods for medium- and heavy-duty applications and ensuring hydrogen quality is maintained. 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.

These efforts are complemented by projects undertaken and supported by the Ca FCP over the last few years including their Medium- and Heavy-Duty Fuel Cell Electric Truck Action Plan released in October 2016 focusing on Class 4 parcel delivery trucks and Class 8 drayage trucks with infrastructure development and establishing metrics for measuring progress, and their Vision 2030 document released in July 2018 establishing a roadmap for future FCV and hydrogen refueling stations, including barriers that need to be overcome.

This project area would enable cofunding support for additional or follow on mutually agreed technical tasks with the California Hydrogen Infrastructure Research Consortium, the CaFCP as well as other collaborative efforts that may be undertaken to advance hydrogen infrastructure technologies.

**Potential Air Quality Benefits:**

The 2016 AQMP identifies the use of alternative fuels and zero emission transportation technologies as necessary to lower NOx and VOC emissions, in an effort to meet federal air quality standards. One of the major advantages of FCVs is the fact that they use hydrogen, a fuel that can be domestically produced from a variety of resources such as natural gas (including biogas), electricity (stationary turbine technology, solar or wind) and biomass. The technology and means to produce hydrogen fuel to support FCVs are available but require optimization to achieve broad market scale. The deployment of large numbers of FCVs, which is one strategy to attain air quality goals, requires a well-planned and robust hydrogen fueling infrastructure network. This South Coast AQMD project, with significant additional funding from other governmental and private entities, will work towards providing the necessary hydrogen fueling infrastructure network.

**Proposed Project:** Develop and Demonstrate Hydrogen Production and Fueling Stations

**Expected South Coast AQMD Cost:** $1,763,000

**Expected Total Cost:** $6,000,000

**Description of Technology and Application:**

Alternative fuels, such as hydrogen and the use of advanced technologies, such as FCVs, 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 refueling 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 refueling and production sites. This project would support the development and demonstration of hydrogen refueling technologies. Proposed projects would address:

*Fleet and Commercial Refueling Stations:* Further expansion of the hydrogen fueling network based on retail models, providing renewable generation, adoption of standardized measurements for hydrogen refueling, other strategic refueling locations and dispensing pressure of up to 10,000 psi and compatibility with existing CNG stations may be considered.

*Energy Stations*: Multiple-use energy stations that can produce hydrogen for FCVs or for stationary power generation are considered an enabling technology with the potential for costs competitive with large-scale reforming. System efficiency, emissions, hydrogen throughput, hydrogen purity and system economics will be monitored to determine the viability of this strategy for hydrogen fueling infrastructure deployment and as a means to produce power and hydrogen from renewable feedstocks (e.g., biomass, digester gas).

*Innovative Refueling Appliances*: Home or small scale refueling/recharging is an attractive advancement for alternative clean fuels due to the limited conventional refueling infrastructure. This project would evaluate a hydrogen innovative 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.

Projections for on-the-road FCVs counts now exceed 23,000 in 2021 and 47,000 in 2024 in California and the majority of these do not include medium- and heavy-duty vehicles that may be deployed in the Basin. To provide fuel for these vehicles, the hydrogen fueling infrastructure needs to be significantly increased and become more reliable in terms of availability. 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 be realized by any momentum created by the Governor's 2018 Executive Order to establish 200 stations by 2025.

**Potential Air Quality Benefits:**

The 2016 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 in effect several fleet rules that require public and certain private fleets to purchase clean-burning alternative-fueled vehicles when adding or replacing vehicles to their vehicle fleets. FCVs constitute some of the cleanest alternative-fuel vehicles today. Since hydrogen is a key fuel for FCVs, this project would address some of the barriers faced by hydrogen as a fuel 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 Medium- and Heavy-Duty Fuel Cell Vehicles

**Expected South Coast AQMD Cost:** $2,644,500

**Expected Total Cost:** $12,000,000

**Description of Technology and Application:**

This proposed project would support evaluation including demonstration of 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 as a way of reducing costs and potentially enhancing performance of FCVs.

The California ZEV Action Plan specifies actions to help deploy an increasing number of ZEVs, including medium- and heavy-duty ZEVs. CARB recently adopted Innovative Clean Transit Bus Regulation as another driver. Fleets are useful demonstration sites because economies of scale exist in central refueling, in training skilled personnel to operate and maintain the vehicles, in the ability to monitor and collect data on vehicle performance and for manufacturer technical and customer support. In some cases, medium- and heavy-duty FCVs could leverage the growing network of hydrogen stations, providing an early base load of fuel consumption until the number of passenger vehicles 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. More recently, the Clean Fuels Program cost-shared the development of transit buses at OCTA and will cost-share the demonstration of trucks and hydrogen stations to support the Port of Los Angeles project. More projects like these are anticipated as the OEMs come on board.

This category may include projects in the following applications:

| **On-Road:** | **Off-Road:** |
|---|---|
| • Transit Buses<br>• Shuttle Buses<br>• Medium- & Heavy-Duty Trucks | • Vehicle Auxiliary Power Units<br>• Construction Equipment<br>• Lawn and Garden Equipment<br>• Cargo Handling Equipment |

**Potential Air Quality Benefits:**

The 2016 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. 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 FCVs. 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 FCVs 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 emission 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 to demonstrate improvements to the reliability and durability of the powertrain systems and hydrogen storage system. 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 and higher density and lower cost batteries.

**Proposed Project:** Demonstrate Light-Duty Fuel Cell Vehicles

**Expected South Coast AQMD Cost:** $88,150

**Expected Total Cost:** $100,000

**Description of Technology and Application:**

This proposed project would support the demonstration of limited production and early commercial light-duty FCVs using gaseous hydrogen with proton exchange membrane (PEM) fuel cell technology, mainly through showcasing this technology. Recent designs of light-duty FCVs include hybrid batteries to recapture regenerative braking and improve overall system efficiency.

With the implementation of the California ZEV Action Plan, supplemented by the existing and planned hydrogen refueling stations in the Southern California area, light-duty limited-production FCVs are planned for retail deployment in early commercial markets near hydrogen stations by several OEMs. Fleets are useful demonstration sites because economies of scale exist in central refueling, in training skilled personnel to operate and maintain the vehicles, in the ability to monitor and collect data on vehicle performance and for OEM technical and customer support. South Coast AQMD has included FCVs as part of its demonstration fleet since it started the Five Cities Program in 2005 with the Cities of Burbank, Ontario, Riverside, Santa Ana, and Santa Monica to deploy 30 hydrogen ICE vehicles and five hydrogen stations. As part of this effort, South Coast AQMD has provided support, education, and outreach regarding FCV technology on an ongoing basis. In addition, demonstration vehicles could include hybrid-electric vehicles powered by fuel cells and equipped with larger batteries capable of being charged from the grid and even supplying power to the grid.

Hyundai, Toyota and Honda have commercialized FCVs in California, but the first commercial FCV leases are ending, and solo carpool lane access extends only for MY 2017 and later, encouraging new replacements. Innovative strategies and demonstration of dual fuel, ZEVs could expand the acceptance of BEVs and accelerate the introduction of fuel cells in vehicle propulsion.

**Potential Air Quality Benefits:**

The 2016 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. 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 FCVs. Expected immediate benefits include the deployment of zero emission vehicles 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 AQMP.

## Engine Systems/Technologies

**Proposed Project**: Develop and Demonstrate Advanced Gaseous- and Liquid-Fueled Medium- and Heavy-Duty Engines and Vehicles Technologies to Achieve Ultra-Low Emissions

**Expected South Coast AQMD Cost:** $2,203,750

**Expected Total Cost:** $12,500,000

**Description of Technology and Application:**

The objective of this proposed project would be to support development and certification of near-commercial prototype low emission medium- and heavy-duty 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. To achieve these targets, an effective emissions control strategy must employ advanced fuel system and engine design features, cylinder deactivation, aggressive engine calibration and improved thermal management, improved exhaust gas recirculation systems, and aftertreatment devices that are optimized using a system approach. This effort is expected to result in several projects, including:

- development and demonstration of advanced engines in medium- and heavy-duty vehicles and high horsepower (HP) applications;
- development of durable and reliable retrofit technologies to partially or fully convert engines and vehicles from petroleum fuels to alternative fuels; and
- field demonstrations of advanced technologies in various fleets operating with different classes of vehicles.

Anticipated fuels for these projects include but are not limited to alternative fuels (fossil fuel-based and renewable natural gas, propane, hydrogen blends, electric and hybrid), conventional and alternative diesel fuels, ultra-low sulfur diesel, renewable diesel, dimethyl ether and gas-to-liquid fuels.

The use of alternative fuel in heavy-duty trucking applications has been demonstrated in certain local fleets within the Basin. These vehicles typically require 200-400 HP engines. Higher HP alternative fuel engines are beginning to be introduced. However, vehicle range, lack or limited accessible public infrastructure, lack of experience with alternative fuel engine technologies and limited selection of appropriate alternative fuel engine products have made it difficult for more firms to consider significant use of alternative fuel vehicles. For example, in recent years, several large trucking fleets have expressed interest in using alternative fuels. However, at this time the choice of engines over 400 HP or more is limited. Continued development of cleaner dedicated alternative gaseous- or diesel-fueled engines over 400 HP with lower NOx emissions, would increase availability to end-users and provide additional emission reductions.

**Potential Air Quality Benefits:**

This project is intended to expedite the commercialization of near-zero emission gaseous- and liquid-fueled medium- and heavy-duty engine technology both in the Basin and in intrastate operation. The emissions reduction benefits of replacing one 4.0 g/bhp-hr heavy-duty engine with a 0.2 g/bhp-hr engine in a vehicle that consumes 10,000 gallons of fuel per year is about 1,400 lb/yr of NOx. A heavy-duty 8.9L and 11.9L engines using natural gas 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 undergoing development. Further, neat or blended alternative fuels can also reduce heavy-duty engine particulate emissions by over 90 percent compared to current diesel technology. This project is expected to lead to increased availability of low emission alternative fuel heavy-duty 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 2016 AQMP control measures.

**Proposed Project:** Develop and Demonstrate Alternative Fuel and Clean Conventional Fueled Light-Duty Vehicles

**Expected South Coast AQMD Cost:** $176,300

**Expected Total Cost:** $1,000,000

**Description of Technology and Application:**

Although new conventionally fueled vehicles are much cleaner than their predecessors, not all match the lowest emissions standards often achieved by alternative fuel vehicles. This project would assist in the development, demonstration and certification of both alternative-fueled and conventional-fueled vehicles to meet the strictest emissions requirements by the state, e.g., SULEV for light-duty vehicles. The candidate fuels include CNG, LPG, ethanol, GTL, clean diesel, modified biodiesel and ultra-low sulfur diesel, and other novel technologies. The potential vehicle projects may include:

- certification of CNG light-duty sedans and pickup trucks used in fleet services;
- assessment of "clean diesel" vehicles, including hybrids and their ability to attain SULEV standards; and
- assessment of other clean technologies.

Other fuel and technology combinations may also be considered under this category.

**Potential Air Quality Benefits:**

The 2016 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 in effect several fleet rules that require public and certain private fleets to purchase clean-burning alternative-fueled vehicles when adding or replacing vehicles to their vehicle fleets. This project is expected to lead to increased availability of low emission alternative-and conventional-fueled vehicles for fleets as well as consumer purchase.

**Proposed Project:** Develop and Demonstrate Low Load and Cold-Start Technologies

**Expected South Coast AQMD Cost:** $176,300

**Expected Total Cost:** $1,000,000

**Description of Technology and Application:**

Cold starts and low loads of internal combustion engines have a negative impact on the environment. The thermal efficiency of the internal combustion engine is significantly lower at cold-starts and lower loads. Exhaust aftertreatment systems require a temperature of 250 degrees Celsius or higher to operate at the highest level of emissions reduction efficiency. Diesel engines at cold start increase emissions as much as 10% compared to spark-ignited CNG engines. At low loads, an aftertreatment system often may operate at 150 degrees Celsius. It is also now known that the smaller hybrid engines are experiencing similar warm-up issues due to the on-off drive cycles. The need for thermal efficiency at start- up has led to a variety of suggestions and trials. The primary goal is to reduce energy losses so that systems and components such as the catalytic converter system reach and maintain their intended operating temperature range as soon as possible after engine start. In most cases, adaptation of algorithms associated with fuel injection timing, cylinder deactivation, EGR fraction, turbo control, heated dosing, SCR pre-heaters and close coupled catalysts can be used to keep the catalyst at the correct operating temperature. This project is to investigate technology to improve catalyst temperature at start-up and low loads with minimal economic impact and time. This technology could be applied to a range of vehicles from hybrid-electric light-duty vehicles to heavy-duty trucks. Emphasis should be on steady temperature control at optimal degrees already proven and established through significant research. The following items are the most recently developed best practices with respect to cost and functionality.

- design and prove cylinder activation technology; and
- develop control algorithms to ensure the catalyst maintains temperature throughout the duty cycle.

The project would be implemented, and fleet tested, and recorded over a minimum 12-month period. Further projects can develop from this technology and should be tested in regard to other liquid fuel burning engines.

**Potential Air Quality Benefits:**

The technology to reduce emissions at cold starts and low loads is beneficial to a broad spectrum of vehicles from hybrid electric, light-duty and heavy-duty engines in drayage long haul trucks. The advancement in this technology will directly contribute toward low NOx required as a result of U.S. EPA's heavy-duty engine standard and the current attainment policies in effect. Eliminating cold starting engine issues also directly creates a co- benefit of reducing fuel consumption.

**Proposed Project:** Develop and Demonstrate Low Emissions Locomotive Technologies

**Expected South Coast AQMD Cost:** $176,300

**Expected Total Cost:** $1,000,000

**Description of Technology and Application:**

The objective of this project is to support the development and demonstration of gaseous and liquid fueled locomotive engines. The requirements of locomotive engines as primary generators of electricity to power the locomotive poses serious challenges. 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 do not currently exist to power locomotives. The early stages of development of engines and systems to fill this need is currently on-going. Engines are expected to be below the current 0.2g/bhp-hr low NOx standard. The adaptation of alternative fueled locomotives in coordination with required infrastructure improvement by leading manufacturers in the industry shows great potential for further research and cost savings with less maintenance costs and better reliability.

**Potential Air Quality Benefits:**

This project is expected to reduce emissions around 97 tons per year of NOx for each locomotive. The reduction of PM and CO2 also shows great potential mitigation in environmental justice communities.

## Electric/Hybrid Technologies and Infrastructure

**Proposed Project:** Develop and Demonstrate Medium- and Heavy-Duty On-Road and Off-Road Electric and Hybrid Vehicles

**Expected South Coast AQMD Cost:** $2,203,750

**Expected Total Cost:** $12,500,000

**Description of Technology and Application:**

The significance of transportation in overall carbon emissions is increasing as energy utilities move toward cleaner and more sustainable ways to generate electricity. The U.S. EPA estimated that in 2016, transportation was responsible for about 28 percent of the nation's carbon emissions, while the electricity sector emissions declined from 31 to 28 percent.

The South Coast AQMD has long been a leader in promoting early demonstrations of next generation light-duty vehicle propulsion technologies (and fuels). However, given the current and planned market offerings in this category, priorities have shifted. Nevertheless, the South Coast AQMD will continue to evaluate market offerings and proposed technologies in light-duty vehicles to determine if any future support is required.

Meanwhile, medium- and heavy-duty vehicles make up 4.3 percent of vehicles in the U.S. and drive 9.3 percent of all vehicle miles traveled each year yet are responsible for more than 25 percent of all the fuel burned annually. Moreover, the AQMP identified medium- and heavy-duty vehicles as the largest source of NOx emissions in the South Coast Air Basin. Electric and hybrid technologies have gained momentum in the light-duty sector with commercial offerings by most of the automobile manufacturers. Unfortunately, the medium- and heavy-duty platforms require the greatest emission reductions, especially for the fleets due to low turnover.

The South Coast AQMD has investigated the use of electric and hybrid technologies to achieve similar performance as the conventional-fueled counterparts while achieving both reduced emissions and improved fuel economy. Development and validation of emissions test procedures is needed but is complicated due to the low volume and variety of medium- and heavy-duty vehicles. In 2019, CARB announced the next stages of lower NOx standards and introduced the new hybrid powertrain certification test procedures. The new test procedures will account for the fuel and emission benefits of hybrid vehicles and allow them to certify to a potentially lower engine standard. South Coast AQMD have made initial contact with several OEMs to develop next generation lower NOx heavy-duty diesel and natural gas hybrid powertrains. Hybrid technologies offers a potentially faster commercialization pathway for reducing both NOx and greenhouse gas emissions in the near term by strategically utilizing the existing internal combustion engines and electric components. These new hybrid powertrains could be used as a bridge to the zero emission technologies. Due to limited time to attainment, continued development and demonstration efforts are much needed in the medium- and heavy-duty sector in order to accelerate the commercialization of next generation hybrid technologies to market.

Platforms to be considered include utility trucks, delivery vans, shuttle buses, transit buses, waste haulers, construction equipment, cranes and other off-road vehicles. Innovations that may be considered for demonstration include advancements in the auxiliary power unit, either ICE or other heat engine; and battery-dominant hybrid systems utilizing off-peak re-charging, with advanced battery technologies. Alternative fuels are preferred in these projects, e.g., natural gas, especially from renewable sources, LPG, hydrogen, GTL and hydrogen-natural gas blends, but conventional fuels such as gasoline, renewable diesel, or even modified biodiesel may be considered if the 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.

As on-road mobile sources are increasingly getting cleaner, the off-road sector has been gaining attention. These sources include cargo handling equipment and off-road construction equipment. Several manufacturers have released electric and hybrid equipment, and more are underway. Since the applications are more diverse in this sector, continued development and incentives are needed to accelerate the progress in this sector.

This project category will develop and demonstrate:

- various EV architectures;
- anticipated costs for such architectures;
- customer interest and preferences for each alternative;
- integration of the technologies into prototype vehicles and fleets;
- electric and hybrid-electric medium- and heavy-duty vehicles (e.g., utility trucks, delivery vans, shuttle buses, transit buses, waste haulers, construction equipment, cranes and other off-road vehicles);
- development and demonstration of electric off-road vehicles, e.g., battery electric off-road construction equipment;
- development and demonstration of CNG hybrid vehicle technology; and
- development and demonstration of diesel hybrid vehicle technology.

**Potential Air Quality Benefits:**

The 2016 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 a conventionally gasoline-fueled combustion engine vehicle, a key factor expected to enhance broad consumer acceptance. Given the variety of EV systems under development, it is critical to determine the true emissions and performance utility compared to conventional 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 AQMP.

**Proposed Project:** Develop and Demonstrate Electric Charging Infrastructure

**Expected South Coast AQMD Cost:** $220,375

**Expected Total Cost:** $1,250,000

**Description of Technology and Application:**

There is a critical need to address gaps in EV charging infrastructure availability. Almost half (48 percent) of the 1,293,728 EVs sold in the U.S. since 2011 were in California, and of those sales in California, it is estimated that almost half (43 percent) of CVRP rebates issued to date were issued in 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.

The revised recommended practice SAE J1772 enables passenger vehicles to charge from 240V AC (Level 2) and 480V DC charging using a common conductive connector in 30 minutes for 90 miles of range (50 kW fast charger) or 40 minutes for 200 miles of range (135 kW Tesla fast charger). Together with the growing adoption of long range EVs above 200-mile electric range, the technology and infrastructure of three fast charging systems (CCS1 in North America and CCS2 elsewhere in the world, CHAdeMO and Tesla) are developing as well, although China adopted a GB/T standard based on CHAdeMO. Technological developments improving the driving range of EVs, as well as increasing availability and speed of charging infrastructure, could change the need for charging infrastructure in the future. However, a study of fast charging impact on battery life and degradation is very limited. The research and demonstration to increase understanding of the degradation effects of fast charging will have implications on what types of charging EV owners will leverage and what EVSE stakeholders will bring to market. South Coast AQMD is committed to continuing to support the successful deployment of EV charging infrastructure as well as demonstration of fast charging effect on battery life, leveraging funds from the state, local utility funds like SCE's Charge Ready and the Volkswagen settlement.

The South Coast AQMD is actively pursuing development of intelligent transportation systems, such as Volvo's EcoDrive software platform being utilized for the ZEDT and Volvo LIGHTS projects, to improve traffic efficiency of battery electric and fuel cell electric cargo container trucks. This system provides truck drivers real-time vehicle operation feedback based on changing traffic and road conditions where trucks can dynamically change their speed to better flow through intersections. EcoDrive is also using geofencing capabilities to operate in zero emissions mode while traveling through disadvantaged communities. A truck eco-routing system can provide the eco-friendliest travel route based on truck engine/emission control characteristics, loaded weight, road grade and real-time traffic conditions. Integrated programs can interconnect fleets of electric drive vehicles with mass transit via web-based reservation systems that allow multiple users. These integrated programs can match the features of EVs (zero emissions, zero start-up emissions, short range) to typical consumer demands for mobility in a way that significantly reduces emissions of pollutants and greenhouse gases.

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

- 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;
- charging infrastructure and innovative systems to support advanced vehicle development projects;
- support investigation of fast charging impact 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 heavy-duty trucks in goods movement.

**Potential Air Quality Benefits:**

The 2016 AQMP identifies zero emission vehicles as a key attainment strategy. 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 petroleum-fueled vehicles to battery and FCVs. In addition, this project will assist in achieving improved fuel economy and lower tailpipe emissions, further helping the region to achieve federal ambient air quality standards 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 South Coast Basin, which is a high priority of the AQMP.

**Proposed Project:** Demonstrate Alternative Energy Storage

**Expected South Coast AQMD Cost:** $176,300

**Expected Total Cost:** $1,500,000

**Description of Technology and Application:**

The South Coast AQMD has been involved in the development and demonstration of energy storage systems for electric and hybrid-electric vehicles, mainly lithium ion chemistry battery packs. Over the past few years, new technologies, especially lithium-ion batteries have shown robust performance. Other technology manufacturers have also developed energy storage devices including beyond lithium-ion batteries, flywheels, hydraulic systems and ultracapacitors. Energy storage systems optimized to combine the advantages of ultracapacitors and high-energy but low-power advanced batteries could yield benefits. Beyond lithium-ion batteries (e.g., lithium-sulfur, lithium-oxygen, sodium-ion, flow, and solid-state batteries) also have opportunities to achieve higher energy density, longer cycle life, and lower cost.

This project category is to apply these advanced storage technologies in vehicle platforms to identify best fit applications, demonstrate their viability (reliability, maintainability and durability), gauge market preparedness, evaluate costs relative to current lithium-ion batteries and provide a pathway to commercialization.

The long-term objective of this project is to decrease fuel consumption and resulting emissions without any changes in performance compared to conventional vehicles. This effort will support several projects for development and demonstration of different types of low emission hybrid vehicles using advanced energy storage strategies and conventional or alternative fuels. The overall net emissions and fuel consumption of these types of vehicles are expected to be much lower than traditional engine systems. Both new and retrofit technologies will be considered.

Additionally, this project will also assess potential for repurposing of electric vehicle batteries for storage as well as the longer term more cost-effective recycling approaches currently in a nascent "pilot" stage, especially for metals such as lithium and cobalt.

**Potential Air Quality Benefits:**

Certification of low emission vehicles and engines and their integration into the Basin's transportation sector is a high priority under the 2016 AQMP. This project is expected to further efforts to develop alternative energy storage technologies that could be implemented in medium- and heavy-duty trucks, buses and other applications. Benefits will include proof of concept for the new technologies, diversification of transportation fuels and lower emissions of criteria, toxic pollutants and greenhouse gases.

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

**Expected South Coast AQMD Cost:** $100,000

**Expected Total Cost:** $100,000

**Description of Technology and Application:**

This proposed project would support the demonstration of limited production and early commercial light-duty BEVs and PHEVs using advanced technology, mainly through showcasing this technology. Recent designs of light-duty BEVs and PHEVs provide increased range before recharging, improved efficiency and recharging times, and other advanced safety, energy, autonomous and performance features in new platforms and applications that can accelerate EV adoption.

South Coast AQMD has included BEVs and PHEVs as part of its demonstration fleet since the development of early conversion vehicles. South Coast AQMD also 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 supporting education and outreach regarding BEV and PHEV technology on an ongoing basis.

Light-duty BEVs and PHEVs are available from most established OEMs and several new OEMs. Since solo carpool lane access extends only for three years through MY 2025 according to current legislation, demonstration vehicle replacement is encouraged.

**Potential Air Quality Benefits:**

The 2016 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. In the future, such vehicles could be powered by BEVs. The proposed projects have the potential to accelerate the 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 FCVs 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.

## Fueling Infrastructure and Deployment (Natural Gas/Renewable Fuels)

**Proposed Project:** Demonstrate Near-Zero emission Natural Gas Vehicles in Various Applications

**Expected South Coast AQMD Cost:** **$**440,750

**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 fleets and owners and operators of heavy-duty vehicles utilizing this clean fuel. Currently, on-road heavy-duty natural gas engines are increasingly being certified to CARB's optional low-NOx standards which are significantly lower in NOx than the current on-road heavy-duty 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 emissions and useable in a wide variety of medium- and heavy-duty applications, such as Class 6 vehicles used in 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, and 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 heavy-duty vehicle consumers to NGVs.

**Potential Air Quality Benefits:**

Natural gas-powered vehicles have inherently lower engine criteria pollutant emissions relative to conventionally fueled vehicles, especially older diesel-powered vehicles. Recently, on-road heavy-duty 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, transit buses will help reduce local emissions and emissions exposure to nearby residents. Natural gas vehicles can also have lower greenhouse gas emissions and can increase energy diversity, help address national energy security objectives, and can reduce biomass waste when produced from such feedstocks. Deployment of additional NGVs is consistent with South Coast AQMD's AQMP to reduce criteria pollutants, and when fueled by RNG supports California's objectives of reducing GHGs and the 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 & Expand Natural Gas Infrastructure

**Expected South Coast AQMD Cost:** $440,750

**Expected Total Cost:** $2,000,000

**Description of Technology and Application**:

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

**Potential Air Quality Benefits:**

The AQMP identifies the use of alternative clean fuels in mobile sources as a key attainment strategy. Heavy-duty NGVs have significantly lower emissions than their diesel counterparts and represent the cleanest internal combustion engine-powered vehicles available today. The project has the potential to significantly reduce the installation and operating costs of NGV refueling stations, and improving vehicle refueling times through improved refueling systems designs and high-flow nozzles. While new or improved NGV stations have an indirect emissions reduction benefit, they help facilitate the introduction of near-zero emission NGVs in private and public fleets in the area, which have a direct emissions reduction benefit. It is expected that natural gas' lower fuel cost relative to diesel and the added financial incentives of renewable natural gas (RNG) under the state's Low Carbon Fuel Standard program and the federal Renewable Fuel Standard program will significantly reduce operating costs of high fuel volume heavy-duty NGVs and attract consumers to this technology. The increased exposure and fleet and consumer acceptance of NGVs would lead to significant and direct reductions in NOx, VOC, CO, PM and toxic compound emissions from mobile sources. Such increased penetration of NGVs will provide direct emissions reductions of NOx, VOC, CO, PM and air toxic compounds throughout the Basin.

**Proposed Project:** Demonstrate Renewable Transportation Fuel Manufacturing and Distribution Technologies

**Expected South Coast AQMD Cost:** $881,500

**Expected Total Cost:** $10,000,000

**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 federal clean air standards. Alternative fuels produced from renewable sources such as waste biomass help to further efforts associated with landfill and waste diversion, greenhouse gas reduction, energy diversity and petroleum dependency. Locally produced renewable fuels further reduces concerns associated with out-of-state production and transmission of fuel as well as helps support the local economy. Renewable fuels recognized as a transportation fuel under the state's Low Carbon Fuel Standard program and the federal government's Renewable Fuel Standard program can provide financial incentives that can significantly reduce the price of fuel and hence the cost of operation of clean, alternative fuel vehicles and providing additional incentive for consumers to purchase and deploy clean, alternative renewable fueled powered vehicles.

The project category will consider the development and demonstration of technologies for the production and use of renewable transportation fuels such as renewable natural gas (RNG), renewable diesel (RD), and renewable hydrogen (RH) from various waste biomass feed stocks including municipal solid wastes, green waste, and biosolids from waste water treatment facilities, from technologies such as 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 natural gas 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 provide supply to users.

**Potential Air Quality Benefits:**

The South Coast AQMD relies on a significant increase in the penetration of zero and near-zero emission vehicles in the South Coast Basin to attain federal clean air standards by 2023 and 2032. This project would help develop a number of renewable transportation fuel production and distribution facilities to improve local production and use of renewable fuels to help reduce transportation costs and losses that can 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 greenhouse gases associated with these waste biomass feedstocks.

## Stationary Clean Fuel Technologies

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

**Expected South Coast AQMD Cost:** $1,322,250

**Expected Total Cost:** $6,000,000

**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 medium-and heavy-duty 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% of Class 4–8 straight trucks sales and 15% of all other truck sales.

The commercialization of zero emission heavy-duty trucks is currently under way with two of the largest manufacturers announcing plans for commercial products in the 2021-2022 timeframe to be introduced in Southern California. Both Daimler and Volvo, which are currently developing battery electric drayage trucks with the South Coast AQMD, are planning commercial products soon. Several fleet operators are planning large deployments of 50 to100 trucks, some at single site locations. Also, CARB is expected to announce in spring 2020 release of a solicitation that seeks projects to deploy 50 or more heavy-duty trucks at a single location. 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 battery electric trucks (BET) each carrying 300+ kW hours of battery-stored energy or fuel cell trucks (FCT) carrying 30-50 kg of hydrogen will require costly infrastructure that creates a barrier for some fleets to adopt zero emission platforms. Many fleet operators do not own but lease their facilities making the capital expenditure of EV or hydrogen infrastructure impossible to recoup in a short period of time. Like the diesel vehicles they presently operate, fleets purchase fuel for their trucks, not the fueling station. 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 refueling. Additionally, if the microgrid equipment is owned by a third party and the energy sold to the fleet through a power purchase agreement, the financial challenge of a large capital investment can be avoided by the fleet operator.

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 refueling 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 all the technologies that make up microgrids already exist including 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 it and continue to operate as an energy island independent from the grid. Having assurance of an uninterrupted fueling source is an important consideration for a fleet operator. Also, if the microgrid is connected to the fleet operator's logistics system, 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 going to travel, it can charge the vehicle with enough energy for the trip so the truck will operate within 20-80% 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 the charging schedules with

150 kW or less powerful chargers which again will have less impact to battery life than the planned higher powered 300+ kW chargers and lower the costs for the charging infrastructure.

The energy demand of electric and fuel cell heavy-duty trucks is substantial; for a 100-vehicle fleet of BETs with 300 kW hours, batteries would require 30 MW hours/day of energy and for a 100-vehicle fleet of FCTs, 2000 kgs/day of hydrogen. Microgrids can provide energy for hydrogen and EV infrastructure and can serve to enable large zero emission vehicle deployments and make refueling economical and reliable. Staff has demonstrated several microgrid projects with the 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 fleet operators 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. Also, 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 that are 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 here in the South Coast Air Basin.

**Potential Air Quality Benefits:**

Microgrids can support large deployments of zero emission medium- and heavy-duty trucks that are necessary to meet the AQMP target of a 45 percent reduction in NOx required by 2023 and an additional 55 percent reduction by 2031. 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 that are in excess of the assumptions in the AQMP and further enhance South Coast AQMD's ability to enforce full-time compliance.

**Proposed Project:** Develop and Demonstrate Renewables-Based Energy Generation Alternatives

**Expected South Coast AQMD Cost:** $264,450

**Expected Total Cost:** $1,000,000

**Description of Technology and Application:**

The objective of this proposed project is to support the 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-fired pumps. Besides renewable technologies, electrolyzer technology could be used to generate hydrogen, a clean fuel. Hydrogen, when used in regular engines, can potentially reduce tail-pipe emissions, while in fuel cells the emissions are reduced to zero.

The 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 natural gas generated from renewable sources for injection into natural gas pipelines, improve reliability and user friendliness and identify markets that could expedite the implementation of successful technologies.

**Potential Air Quality Benefits:**

The 2016 AQMP identifies the development and ultimately the implementation of non-polluting power generation. To gain the maximum air quality benefit, 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.

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

## Fuel/Emissions Studies

**Proposed Project:** Conduct In-Use Emissions Studies for Advanced Technology Vehicle Demonstrations

**Expected South Coast AQMD Cost:** $308,525

**Expected Total Cost:** $850,000

**Description of Technology and Application:**

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

In addition, South Coast AQMD has been supporting rapid deployment of near-zero emission natural gas technologies ever since the first heavy-duty engine is commercially available in 2015. As more near-zero emission natural gas technology penetrate the different segments, in-use assessment of real-world benefit is needed.

The environmental benefit for each technology class is duty-cycle and application specific. Identifying the attributes of a specific application or drive cycle that would take best advantage of a specific transportation technology would speed the adoption and make optimal use of financial resources in the demonstration and deployment of a technology. The adoption rates would be accelerated since the intelligent deployment of a certain technology would ensure that a high percentage of the demonstration vehicles showed positive results, which would spur the adoption of this technology in similar applications, as opposed to negative results derailing the further development or deployment of a certain technology.

The proposed project would review and potentially coordinate application specific drive cycles to for specific applications. The potential emissions 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.

Another proposed project would be the characterization of intermediate volatility organic compound (IVOC) emissions which is critical in assessing ozone and SOA precursor production rates. Diesel vehicle exhaust and unburned diesel fuel are major sources of and contribute to the formation of urban ozone and secondary organic aerosol (SOA), which is an important component of PM2.5.

Finally, while early developments in autonomous and vehicle-to-vehicle controls are focused on light-duty passenger vehicles, the early application of this technology to heavy-duty, drayage and container transport technologies is more likely. The impact on efficiency and emissions could be substantial. A project to examine this technology to assess its effect on goods movement and emissions associated with goods movement could be beneficial at this time.

**Potential Air Quality Benefits:**

The development of an emissions reduction database, for various application specific transportation technologies, would assist in the 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 a significant environmental benefit. The demonstration of a quantifiable reduction in operating cost through the

intelligent deployment of vehicles will also accelerate the commercial adoption of the various technologies. The accelerated adoption of lower emitting vehicles will further assist in attaining South Coast AQMD's air quality goals.

**Proposed Project:** Conduct Emissions Studies on Biofuels, Alternative Fuels and Other Environmental Impacts

**Expected South Coast AQMD Cost:** $440,750

**Expected Total Cost:** $1,500,000

**Description of Technology and Application:**

The use of biofuels can be an important strategy to reduce petroleum dependency, air pollution and greenhouse gas emissions. Biofuels are in fact 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 biofuel use, it is the objective of this project to further analyze these fuels to better understand their benefits and impacts not only on greenhouse gases but also air pollution and associated health effects.

In various diesel engine studies, replacement of petroleum diesel fuel with biodiesel fuel has demonstrated reduced PM, CO and air toxics emissions. Biodiesel also has the potential to reduce greenhouse gas emissions because it can be made from renewable feedstocks, such as soy and canola. However, certain blends of biodiesel have a tendency to increase NOx emissions for certain engines and duty cycles, which exacerbates the 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 to further increase the ethanol content to 10% as a means to increase the amount of renewable fuels in the state. It is projected that the state's ethanol use will increase from 900 million gallons in 2007 to 1.5 billion gallons by 2012 as a result. As in the case of biodiesel, ethanol has demonstrated in various emission studies to reduce PM, CO and toxic emissions; however, the relationship between particle composition and associated health effects from the combustion of ethanol is not well understood either.

CARB recently proposed a regulation on the commercialization of alternative diesel fuels, including biodiesel and renewable diesel, while noting that biodiesel in older heavy-duty vehicles can increase NOx and the need for emerging alternative diesel fuels to have clear ground rules for commercialization. The impact of natural gas fuel composition on emissions from heavy-duty trucks and transit buses is also being studied. Researchers has proposed to evaluate the emissions impact of renewable natural gas and other natural gas blends such as renewable hydrogen.

In order to address these concerns on potential health effects associated with biofuels, namely biodiesel and ethanol blends, this project will investigate the physical and chemical composition and associated health effects of tailpipe PM emissions from light- to heavy-duty vehicles burning biofuels in order 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 for biofuels. Additionally, a study of emissions from well-to-wheel for the extraction and use of shale gas might be considered.

More recently, the Power-to-Gas concept has renewed interest in hydrogen-fossil fuel blends which the emissions impact on latest ICE technologies needs to be reassessed. Hydrogen fueled ICE was studied heavily in the early 2000's and results has shown significant criteria emissions reduction possible with optimized engine calibration. Since then, ICE technologies have been fitted with advanced aftertreatment to allow the engines to be certified to today's NOx and low NOx standards. Therefore, emissions impact assessment is much needed on the latest engines.

Lastly, in an effort to evaluate the contribution of meteorological factors to high ozone and PM2.5 episodes occurring in the Basin, mainly as a result of higher summer time temperatures and increased air stagnation following the drought years, a comprehensive study is necessary to evaluate the trends

of meteorological factors that may adversely impact air quality in the Basin. The study will assist staff to better understand the potential impact of recent weather trends on criteria pollutant emissions and potentially develop 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 any NOx impact, this technology will become a viable strategy to assist 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 the emission benefits and any tradeoffs (NOx impact) that may result from using this alternative fuel. With reliable information on the emissions from using biodiesel and biodiesel blends, the South Coast AQMD can take actions to ensure the use of biodiesel will obtain air pollutant reductions without creating additional NOx emissions that may exacerbate the Basin's ozone problem. Additionally, understanding meteorological factors on criteria pollutant emissions may help identify ways to mitigate them, possibly through targeted advanced transportation deployment.

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

**Expected South Coast AQMD Cost:** $220,375

**Expected Total Cost:** $1,000,000

**Description of Technology and Application:**

New technologies, such as alternative fueled heavy-duty 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 the vehicle maintenance needs, repair history, tire pressure and fuel economy. Telematics have been shown to reduce emissions from new vehicles. Unfortunately, the in-use fleet lacks telematic systems--particularly heavy-duty engines in trucks, buses, construction equipment, locomotives, commercial harbor craft and cargo handling equipment--have fairly long working lifetimes (up to 20 years due to remanufacturing in some cases). Even light-duty vehicles routinely have lifetimes exceeding 200,000 miles and 10 years. And it is the in-use fleet, especially the oldest vehicles, which are responsible for the majority of emissions.

This project category is to investigate near-term emissions 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 heavy-duty vehicles;
- annual testing for high mileage vehicles (>100,000 miles);
- replace or upgrade emissions 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; and
- low NOx sensor development

**Potential Air Quality Benefits:**

Many of the technologies identified can be applied to light- and heavy-duty 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. The identification and replacement of high-emitting vehicles has been identified in CERPs from the Year 1 AB 617 communities as a high priority for residents living in these communities, particularly as heavy-duty trucks frequently travel on residential streets to bypass traffic on freeways surrounding these disadvantaged communities.

## Emissions Control Technologies

**Proposed Project:** Develop and Demonstrate Advanced Aftertreatment Technologies

**Expected South Coast AQMD Cost:** $176,300

**Expected Total Cost:** $2,000,000

**Description of Technology and Application**:

There are a number of aftertreatment technologies which have shown substantial emissions reductions in diesel engines. These technologies include zoned catalyst soot filters, early light -off catalysts, dual SCR systems, pre-NOx absorbers, and ammonia slip catalysts. Additional heating technologies available to keep desired catalyst temperatures such as heated dosing and heated catalysts are also part of the complete aftertreatment system design for near-zero emission NOx. This project category is to develop and demonstrate these aftertreatment technologies alone or in tandem with an alternative fuel to produce the lowest possible PM, ultrafine particles, nanoparticles, NOx, CO, carbonyl and hydrocarbon emissions in retrofit and new applications. With the increasing focus on zero and near-zero emissions goods movement technologies, this category should examine idle reduction concepts and technologies that can be employed at ports and airports.

Possible projects include advancing the technologies for on-road retrofit applications, such as heavy-duty line-haul and other large displacement diesel engines, street sweepers, waste haulers and transit buses. Applications for non-road may include construction equipment, yard hostlers, gantry cranes, locomotives, commercial harbor craft, ground support equipment and other similar industrial applications. Potential fuels to be considered in tandem are low-sulfur diesel, emulsified diesel, biodiesel, gas-to-liquids, hydrogen and natural gas. This project category will also explore the performance, economic feasibility, viability (reliability, maintainability and durability) and ease-of-use to ensure a pathway to commercialization.

**Potential Air Quality Benefits:**

The transfer of mature emission control technologies, such as DPFs and oxidation catalysts, to the off-road sector is a potentially low-risk endeavor that can have immediate emissions reductions. Further development and demonstration of other technologies, such early light –off SCR and heated dosing, could also have NOx reductions of up to 90%.

**Proposed Project:** Develop and Demonstrate Advanced Aftertreatment Catalyst Heating Technologies

**Expected South Coast AQMD Cost:** $220,375

**Expected Total Cost:** $1,000,000

**Description of Technology and Application:**

The objective of this project is to support the demonstration and integration of aftertreatment systems incorporating technologies such as heated dosing and electrically heated catalysts used for on-road heavy duty vehicles. Current aftertreatment systems are required to maintain an operating temperature of 200 °C or higher for optimal performance. Diesel engines for heavy duty commercial vehicles have been discovered to operate at temperatures below 200 °C during specific parts of the driving cycle, such as low loads and cold starts. Emissions during the low-load and cold starts have been shown to increase up to 30% and PM up to 20%. Previous technologies, such as the mini-burner, were successful mitigating the cold catalyst issue. There were draw backs in this technology due to increased CO2 emissions. The mini burner was not favorable as a successful approach because it increased fuel consumption. New aftertreatment technologies, coupled with advanced engine technologies, have shown potential to reduce emissions up to 99% without a fuel penalty. Technologies such as:

- Close-coupled catalysts
- Dual-heated diesel-exhaust fluid dosing
- Heated catalysts

Current aftertreatment design incorporates a close-coupled catalyst, selective catalyst reduction filter, dual SCR, and an ammonia–slip catalyst. Included in this design is a required heat source at low loads, cold starts and motoring conditions. The use of an electric heat source has become feasible due to advancements in electrical-powered applications and integration with the vehicle.

**Potential Air Quality Benefits:**

This project is expected to contribute to the total emission reductions in heavy-duty on road engines. Emission reductions of 80-90% in heavy-duty diesel long-haul trucks has already been proven when an advanced aftertreatment system, incorporating an additional heat source, along with advanced engine technology such as cylinder deactivation is used. The fuel savings benefit is especially attractive to long-haul fleet operations. In order to meet the ultra-low NOx air quality standards and promote a national low NOx standard for heavy-duty diesel engines, an advanced aftertreatment system incorporating heated catalyst technology is required.

**Proposed Project:** Develop Methodology and Evaluate Onboard Emission Sensors for On-Road Heavy-Duty Vehicles

**Expected South Coast AQMD Cost:** $220,375

**Expected Total Cost:** $1,100,000

**Description of Technology and Application:**

New heavy-duty on-road vehicles represent one of the largest categories in the NOx emissions inventory in the Basin. In order to meet the 2023 and 2031 ozone standards, NOx emissions need to be reduced by 45% and an additional 55% from 2012 levels, respectively, mainly from mobile sources. Previous in-use emission studies, including studies funded by the South Coast AQMD, have shown significantly higher NOx emissions from on-road heavy-duty vehicles than the certification limit under certain in-use operations, such as low power duty cycles. In CARB's proposed Heavy-Duty On-Road "Omnibus" Low NOx regulation, multiple lower NOx standards will be phased in starting in 2022. In addition to the lower certification values, a low load test cycle, revisions to the not-to-exceed compliance test and NOx sensor data reporting are also proposed 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 the sensors to better monitor emissions compliance and leverage the real-time data from sensors to enable advances concepts such as geofencing.

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 of existing 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 natural gas and other mobile sources such as light-duty, 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. Reduction of NOx and PM emissions from mobile sources is imperative for the Basin to achieve federal ambient air quality standards and protect public health.

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

**Expected South Coast AQMD Cost:** $176,300

**Expected Total Cost:** $800,000

**Description of Technology and Application:**

On-road heavy-duty engines have demonstrated progress in meeting increasingly stringent federal and state requirements. New heavy-duty 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 the engine size. For example, Tier 3 standards for heavy-duty 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 require a repower (engine exchange) to only meet the same emissions standards as the engine being retired. Unfortunately, this does not take advantage of recently developed clean technologies.

Exhaust gas cleanup strategies, such as SCR, 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 the 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 in off-road applications including yard hostlers, switcher locomotives, gantry cranes, waste haulers and construction equipment;
- implementing lower emission engines in repower applications for both on-road and off-road applications; and
- applying stationary best available control technologies, such as SCR, scrubbers, baghouses and electrostatic precipitators, to appropriate on- and off-road applications, such as idling locomotives, commercial harbor craft at dock and heavy-duty line-haul trucks at weigh stations.

**Potential Air Quality Benefits:**

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

## Health Impacts Studies

**Proposed Project:** Evaluate Ultrafine Particle Health Effects

**Expected South Coast AQMD Cost:** $88,150

**Expected Total Cost:** $1,000,000

**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 of the toxic air contaminant emitted from diesel exhaust. Additionally, health studies indicate that the ultrafine portion of particulate matter may be more toxic on a per-mass basis than other fractions. Several technologies have been introduced and others are under development to reduce diesel emissions. These include among others low-sulfur diesel fuel, particulate matter traps and heavy-duty engines operating on alternative fuel such as CNG and LNG. 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 the number of ultrafine particles 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 the new technologies and the health effects of these emissions, an evaluation and comparison of ultrafine particulate matter and the potential impacts on community exposures are necessary.

In this project, measurements and chemical composition of ultrafine particulates will be done, as well as studies conducted to characterize their toxicity. The composition of the particulates can further be used to determine the contribution from specific combustion sources. Additionally, engine or chassis dynamometer testing may be conducted on heavy-duty vehicles to measure, evaluate and compare ultrafine particulate matter, PAH and other relevant toxic emissions from different types of fuels such as CNG, low-sulfur diesel, biofuels and others. This project needs to be closely coordinated with the development of technologies for alternative fuels, aftertreatment and new engines in order to determine the 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 the SOA potential from these vehicles as it could lead to further impact on the ambient PM concentration in our region. Consequently, in 2015 a project was initiated with UCR/CE-CERT to investigate the physical and chemical composition of aerosols from GDI vehicles using a mobile environmental chamber that has been 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.

**Potential Air Quality Benefits:**

The AQMP for the South Coast Basin relies on significant penetration of low emission vehicles to attain federal clean air standards. Reduction of particulate emissions from the 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 ultrafine particulates generated by different types of fuels and advanced control technologies as well as provide information on potential health effects of ultrafine particles. 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

**Expected South Coast AQMD Cost:** $132,225

**Expected Total Cost:** $500,000

**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, distribution centers and freeways is important to identify the emissions exposure to the surrounding communities and provide the data to then conduct the health impacts due to these sources. This project category would identify areas of interest and conduct ambient air monitoring, conduct emissions monitoring, analyze the data and assess the potential health impacts from mobile sources. The projects would need to be at least one year in duration in order to properly assess the air quality impacts in the area.

**Potential Air Quality Benefits:**

The proposed project will assist in the 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; 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 Toxic Air Contaminants

**Expected South Coast AQMD Cost:** $132,225

**Expected Total Cost:** $300,000

**Description of Technology and Application:**

Previous studies of ambient levels of toxic air contaminants, such as the MATES series of studies, have found that diesel exhaust is the major contributor to health risk from air toxics. Analyses of diesel particulate matter 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 diesel particulate matter as well as estimate levels of particulate matter 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, an updated emissions inventory of toxic air contaminants and a to air toxics, MATES IV also measured ultrafine particle concentrations and black carbon at the monitoring sites as well as near sources such as airports, freeways, rail yards, busy intersections and warehouse operations.

MATES V was launched in 2017 to update the emissions inventory of toxic air contaminants and modeling to characterize risks, including measurements and analysis of ultrafine particle concentrations typically emitted or converted from vehicle exhaust. Based on preliminary results of MATES V, further assessment may need to be performed to assess secondary organic aerosols; including installation of sensors and additional monitoring activities.

This project category would include other related factors, such as toxicity assessment based on age, source (heavy-duty, light-duty engines) and composition (semi-volatile or non-volatile fractions) to better understand the health effects and potential community exposures. 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 diesel particulate matter as well as levels of particulate matter from other significant combustion sources, including gasoline and diesel generated VOCs. This will allow a better estimation of potential exposures to and health effects from toxic air contaminants from diesel exhaust in the Basin. This information in turn can be used to determine the health benefits of promoting clean fuel technologies.

## Technology Assessment/Transfer and Outreach

**Proposed Project:** Assess and Support Advanced Technologies and Disseminate Information

**Expected South Coast AQMD Cost:** $352,600

**Expected Total Cost:** $800,000

**Description of Project:**

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

This project may include the following:

- technical review and assessment of technologies, projects and proposals;
- support for alternative fuel refueling and infrastructure;
- advanced technology curriculum development, mentoring and outreach to local schools;
- emissions studies and assessments of zero emission alternatives;
- preparation of reports, presentations at conferences, improved public relations and public communications of successful demonstrations of clean technologies;
- participation in and coordination of workshops and various meetings;
- support for training programs related to fleet operation, maintenance and refueling of alternative fuel vehicles;
- publication of technical papers as well as reports and bulletins; and
- production and dissemination of information, including websites.

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 and associated infrastructure.

**Potential Air Quality Benefits:**

South Coast AQMD adopted fleet regulations requiring public and private fleets within the Basin to acquire alternatively fueled vehicles when making new purchases. Expected benefits of highlighting success stories in the use of advanced alternatively fueled vehicles could potentially expedite the acceptance and commercialization of advanced technologies by operators seeking to comply with the provisions of the recently adopted South Coast AQMD fleet rules. The resulting future emissions benefits will contribute to the goals of the AQMP.

**Proposed Project:** Support Implementation of Various Clean Fuels Vehicle Incentive Programs

**Expected South Coast AQMD Cost:** $264,450

**Expected Total Cost:** $400,000

**Description of Project:**

This project supports the implementation of ZEV incentive programs, the Carl Moyer incentives program, school bus incentive program, and the South Coast AQMD residential EV charger rebate program. Implementation support includes application review and approval, grant allocation, documentation to the CARB, verification of vehicle operation and other support as needed. Information dissemination is critical to successful implementation of a coordinated and comprehensive package of incentives. Outreach will be directed to vehicle dealers, individuals and fleets. To date, the South Coast AQMD residential EV charger rebate program, which is jointly supported by the South Coast AQMD Clean Fuels Fund ($500,000) and the Mobile Source Air Pollution Reduction Review Committee (MSRC) for $500,000, has provided over 1,300 rebates and $360,000 in funding to residents in the South Coast AQMD jurisdiction.

**Potential Air Quality Benefits:**

As described earlier, the South Coast AQMD will provide matching funds to implement several key incentives programs to reduce diesel emissions in the Basin. Furthermore, the South Coast AQMD recently adopted fleet regulations requiring public and private fleets within the Basin to acquire alternatively fueled vehicles when making new purchases. Expected benefits of highlighting zero emission vehicle incentives could potentially expedite the acceptance and commercialization of advanced technologies by operators seeking to comply with the provisions of the recently adopted South Coast AQMD fleet rules. The resulting future emissions benefits will contribute to the goals of the AQMP. The school bus program and the Carl Moyer incentives program will also reduce large amounts of NOx and PM emissions in the basin in addition to reducing toxic air contaminants.

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# Appendix A

# South Coast AQMD Advisory Groups

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# Technology Advancement Advisory Group[1]

| | |
|---|---|
| Dr. Matt Miyasato, Chair | South Coast AQMD |
| Don Anair | Union of Concerned Scientists |
| Chris Cannon | Port of Los Angeles |
| Steve Cliff | 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 |
| Phil Heirigs | Western States Petroleum Association |
| *Vic La Rosa | Total Transportation Solutions Inc. |
| Tim Olson | California Energy Commission |
| David Pettit | Natural Resources Defense Council |
| Dr. Sunita Satyapal | Department of Energy |
| Heather Tomley | Port of Long Beach |
| Dawn Wilson | Southern California Edison |

*newly appointed member

[1] Members as of February 14, 2020

# SB 98 Clean Fuels Advisory Group[2]

| | |
|---|---|
| Dr. Matt Miyasato, Chair | South Coast AQMD |
| *Steve Ellis | American Honda Motor Company Inc. |
| Dr. John Budroe | California Environmental Protection Agency, Office of Environmental Health Hazard Assessment |
| *Dr. John Wall | Independent Consultant in Combustion Technology |
| Dr. Mark Duvall | 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 |
| Dr. Robert Sawyer | Sawyer Associates |
| Andreas Truckenbrodt | Independent Consultant in Fuel Cell Technologies |
| Kevin Walkowicz | National Renewable Energy Laboratory |
| Michael Walsh | Independent Consultant in Motor Vehicle Pollution Control |

*newly appointed member

[2] Members as of February 14, 2020

# Appendix B

# Open Clean Fuels Contracts as of January 1, 2020

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| Contract | Contractor | Project Title | Start Term | End Term | South Coast AQMD $ | Project Total $ |
|---|---|---|---|---|---|---|
| Hydrogen and Mobile Fuel Cell Technologies and Infrastructure | | | | | | |
| 15150 | Air Products and Chemicals Inc. | Install and Upgrade Eight Hydrogen Fueling Stations Throughout SCAB (including South Coast AQMD's Diamond Bar Hydrogen Station) | 10/10/14 | 04/09/20 | 1,000,000 | 17,335,439 |
| 15366 | EPC LLC | Operate and Maintain Publicly Accessible Hydrogen Fueling Station at South Coast AQMD's Headquarters | 10/10/14 | 04/09/20 | 0 | 0 |
| 15609 | ITM Power, Inc. | Installation of Riverside Renewable Hydrogen Fueling Station | 10/06/15 | 01/31/20 | 200,000 | 2,325,000 |
| 15611 | Ontario CNG Station, Inc. | Installation of Ontario Renewable Hydrogen Fueling Station | 07/10/15 | 07/09/20 | 200,000 | 2,325,000 |
| 15618 | FirstElement Fuel, Inc. | Installation of Eight Hydrogen Stations in Various Cities (two renewable, six delivered) | 02/05/16 | 02/04/21 | 1,000,000 | 16,442,000 |
| 15619 | H2 Frontier Inc. | Installation of Chino Renewable Hydrogen Station | 12/04/15 | 12/03/20 | 200,000 | 4,558,274 |
| 15635 | Center for Transportation and Environment | ZECT II: Develop and Demonstrate One Class 8 Fuel Cell Range-Extended Electric Drayage Truck | 04/27/16 | 10/26/20 | 821,198 | 7,109,384 |
| 16025 | Center for Transportation and Environment | Develop and Demonstrate Fuel Cell Hybrid Electric Medium-Duty Trucks | 02/05/16 | 08/04/20 | 980,000 | 7,014,000 |
| 16251 | H2 Frontier, Inc. | Develop and Demonstrate Commercial Mobile Hydrogen Fueler | 05/06/16 | 05/05/21 | 200,000 | 1,665,654 |
| 17059 | Calstart Inc. | Develop and Demonstrate Fuel Cell Extended-Range Powertrain for Parcel Delivery Trucks | 10/27/16 | 02/29/20 | 589,750 | 1,574,250 |
| 17312 | Hydrogenics USA Inc. | ZECT II: Develop Fuel Cell Range-Extended Drayage Truck | 11/20/17 | 05/19/21 | 125,995 | 2,433,553 |
| 17316 | Center for Transportation and the Environment | Develop and Demonstrate Ten Zero Emission Fuel Cell Electric Buses | 06/09/17 | 04/30/20 | 1,000,000 | 45,328,859 |
| 17317 | American Honda Motor Company, Inc. | Three Year Lease of One Honda 2017 Clarity Fuel Cell Vehicle for TAO's Fleet Demonstration Program | 03/22/17 | 03/21/20 | 17,304 | 17,304 |
| 17343 | American Honda Motor Company, Inc. | Three Year Lease of One Honda 2017 Clarity Fuel Cell Vehicle for TAO's Fleet Demonstration Program | 02/21/17 | 02/20/20 | 17,328 | 17,328 |
| 17385 | American Honda Motor Company, Inc. | Three Year Lease of One Honda 2017 Clarity Fuel Cell Vehicle for TAO's Fleet Demonstration Program | 05/17/17 | 05/16/20 | 17,304 | 17,304 |
| 18150 | California Department of Food and Agriculture, Division of Measurement Standards | Conduct Hydrogen Station Site Evaluations for Hydrogen Station Equipment Performance (HyStEP) Project | 06/28/18 | 02/27/20 | 100,000 | 805,000 |

| Contract | Contractor | Project Title | Start Term | End Term | South Coast AQMD $ | Project Total $ |
|---|---|---|---|---|---|---|
| Hydrogen and Mobile Fuel Cell Technologies and Infrastructure (cont'd) | | | | | | |
| 18158 | Alliance for Sustainable Energy, LLC (on behalf of National Renewable Energy Laboratory) | California Hydrogen Infrastructure Research Consortium H2 @ Scale Initiative | 08/31/18 | 03/30/20 | 100,000 | 760,000 |
| 19172 | Longo Toyota | Three-Year Lease of Two 2018 Toyota Mirai Fuel Cell Vehicles | 10/28/18 | 10/27/21 | 35,108 | 35,108 |
| 19191 | University of California Irvine | Development of Solid Oxide Fuel Cell and Gas Turbine (SOFC-GT) Hybrid Technology | 06/21/19 | 06/20/20 | 200,000 | 900,000 |
| 19248 | Tustin Hyundai | Three Year Lease of 2019 Fuel Cell Hyundai Nexo | 03/07/19 | 03/06/22 | $25,193 | $25,193 |
| 20038 | University of California Irvine | Expand Hydrogen Fueling Station | 10/18/19 | 02/17/27 | $400,000 | $1,800,000 |
| Engine Systems and Technologies | | | | | | |
| 17197 | VeRail Technologies Inc. | Develop and Demonstrate Ultra-Low Emission Natural Gas Switcher Locomotive | 03/03/17 | 09/30/20 | 1,000,000 | 5,100,000 |
| 17393 | Southwest Research Institute | Develop Ultra-Low Emissions Diesel Engine for On-Road Heavy-Duty Vehicles | 05/30/18 | 01/31/20 | 575,000 | 1,325,000 |
| 18194 | CALSTART Inc. | Develop and Demonstrate Near-Zero Emissions Opposed Piston Engine | 05/30/18 | 07/31/20 | 1,000,000 | 15,500,000 |
| 18122 | Clean Energy | Southern California Trucking Demonstration of Near-Zero ISX12N Beta Engines | 01/05/18 | 01/04/20 | 3,495,000 | 5,995,000 |
| 18211 | West Virginia University Innovation Corporation | Develop Thermal Management Strategy Using Cylinder Deactivation for Heavy-Duty Diesel Engines | 06/08/18 | 06/07/20 | 250,000 | 700,000 |
| 19439 | Cummins, Inc. | Natural Gas Engine and Vehicles Research and Development | 08/30/19 | 08/29/23 | 250,000 | 10,996,626 |
| Electric/Hybrid Technologies and Infrastructure | | | | | | |
| 13433 | U.S. Hybrid Corporation | Develop and Demonstrate Two Class 8 Zero-Emission Electric Trucks | 06/26/13 | 3/31/20 | 75,000 | 150,000 |
| 14052 | Altec Capital Services, LLC | Lease of Two Plug-In Hybrid Electric Vehicles | 01/02/15 | 01/01/20 | 61,302 | 61,302 |
| 14184 | Clean Fuel Connection Inc. | DC Fast Charging Network Provider | 04/04/14 | 06/30/20 | 920,000 | 1,220,000 |
| 16022 | Gas Technology Institute | ZECT II: Develop and Demonstrate One Class 8 CNG Hybrid Electric Drayage Truck | 12/04/15 | 06/30/20 | 1,578,802 | 5,627,319 |
| 16046 | Transportation Power, Inc. | ZECT: Develop and Demonstrate Two Class 8 CNG Plug-In Hybrid Electric Drayage Trucks | 12/04/15 | 3/31/20 | 195,326 | 2,103,446 |
| 16081 | Broadband TelCom Power, Inc. | Provide EV Hardware and Control System at South Coast AQMD Headquarters including Installation Support, Warranty and Networking | 04/27/16 | 04/26/22 | 367,425 | 367,425 |

| Contract | Contractor | Project Title | Start Term | End Term | South Coast AQMD $ | Project Total $ |
|---|---|---|---|---|---|---|
| Electric/Hybrid Technologies and Infrastructure (cont'd) | | | | | | |
| 16200 | California State University Los Angeles | Cost-Share Regional Universities for U.S. DOE EcoCAR 3 Competition | 04/14/16 | 04/15/20 | 100,000 | 300,000 |
| 17029 | University of California Irvine | Demonstrate and Evaluate Plug-In Smart Charging at Multiple Electric Grid Scales | 06/29/17 | 06/28/20 | 250,000 | 750,000 |
| 17065 | Clean Fuel Connection, Inc. | EV Infrastructure Installer | 12/02/16 | 12/31/21 | 805,219 | 805,219 |
| 17105 | BYD Motors Inc. | Develop and Demonstrate Up to 25 Class 8 Battery Electric Drayage Trucks | 04/14/17 | 10/13/23 | 794,436 | 8,942,400 |
| 17207 | Peterbilt Motors | Develop and Demonstrate Up to 12 Class 8 Battery Electric Drayage Trucks | 04/07/17 | 10/06/23 | 642,436 | 11,006,340 |
| 17225 | Volvo Technology of America LLC | Develop and Demonstrate Up to Two Class 8 Battery Electric Drayage Trucks | 06/09/17 | 06/08/20 | 1,741,184 | 9,458,446 |
| 17244 | Kenworth Truck Company | Develop and Demonstrate Up to Two Class 8 Battery Electric Drayage Trucks | 09/08/17 | 01/08/20 | 2,823,475 | 9,743,739 |
| 17353 | Odyne Systems, LLC | Develop and Demonstrate Medium-Heavy-Duty (Class 5-7) Plug-In Hybrid Electric Vehicles for Work Truck Applications | 06/09/17 | 09/08/20 | 900,000 | 6,955,281 |
| 18075 | Selman Chevrolet Company | Lease Two 2017 Chevrolet Bolt All-Electric Vehicles for Three Years for TAO's Fleet Demonstration Program | 08/18/17 | 08/17/20 | 26,824 | 26,824 |
| 18129 | Electric Power Research Institute | Versatile Plug-In Auxiliary Power System Demonstration | 06/28/18 | 06/27/20 | 125,000 | 273,000 |
| 18151 | Rail Propulsion System | Develop and Demonstrate Battery Electric Switcher Locomotive | 04/05/18 | 12/30/20 | 210,000 | 925,000 |
| 18232 | Hyster-Yale Group Inc. | Electric Top-Pick Development, Integration and Demonstration | 09/14/18 | 09/13/21 | 2,931,805 | 3,678,008 |
| 18277 | Velocity Vehicle Group DBA Los Angeles Truck Centers LLC | Southern California Advanced Sustainable Freight Demonstration | 09/07/18 | 03/06/22 | 3,568,300 | 4,198,000 |
| 18280 | Honda of Pasadena | Three-Year Lease of One Honda 2018 Clarity Plug-In Vehicle | 02/07/18 | 02/06/21 | 18,359 | 18,359 |
| 18287 | EVgo Services LLC | Charging Station and Premises Agreement for Installation of One DC Fast Charger at South Coast AQMD Headquarters | 06/27/18 | 06/26/28 | 0 | 0 |
| 18397 | Port of Long Beach | Demonstrate Zero Emission Cargo Handling Vehicle at POLB | 01/04/19 | 05/31/20 | 350,000 | 8,668,410 |
| 19166 | Phoenix Cars LLC dba Phoenix Motorcars | Southern California Airports – Zero Emission Shuttle Transportation | 01/31/19 | 01/30/22 | 3,122,426 | 7,311,456 |
| 19190 | Daimler Trucks North America | Zero Emissions Trucks and EV Infrastructure Project | 12/18/18 | 06/20/22 | 8,230,072 | 31,340,144 |
| 19182 | Los Angeles County | Assistance with Mercedes-Benz USA, LLC Electric Vehicle Chargers Donations | TBD | TBD | 0 | 0 |

| Contract | Contractor | Project Title | Start Term | End Term | South Coast AQMD $ | Project Total $ |
|---|---|---|---|---|---|---|
| Electric/Hybrid Technologies and Infrastructure (cont'd) | | | | | | |
| 19183 | Southern California Public Power Authority (SCPPA) | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 01/10/19 | 01/10/22 | 0 | 0 |
| 19202 | City of Compton | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 04/11/19 | 04/10/22 | 0 | 0 |
| 19250 | Baldermar Caraveo | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 03/06/19 | 03/05/22 | 0 | 0 |
| 19251 | Gary Brotz | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 03/27/19 | 03/26/22 | 0 | 0 |
| 19252 | Hui Min Li Chang | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 03/29/19 | 03/28/22 | 0 | 0 |
| 19253 | Jennifer Chin | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 04/19/19 | 04/18/22 | 0 | 0 |
| 19254 | Liping Huang | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 04/11/19 | 04/18/22 | 0 | 0 |
| 19255 | Ramona Manning | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 04/05/19 | 04/04/22 | 0 | 0 |
| 19256 | Tony Chu | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 04/04/19 | 04/03/22 | 0 | 0 |
| 19278 | Volvo Group North America, LLC | Develop and Demonstrate Zero Emissions Heavy-Duty Trucks, Freight Handling Equipment, EV Infrastructure and Renewable Energy- Low Impact Green Heavy Transport Solutions (LIGHTS) | 04/14/19 | 06/30/21 | 4,000,000 | 91,246,900 |
| 19279 | Douglas Harold Boehm | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 03/29/19 | 03/28/22 | 0 | 0 |
| 19280 | Emile I. Guirguis | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 04/19/19 | 04/18/22 | 0 | 0 |
| 19281 | Helen Chi | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 03/27/19 | 03/26/22 | 0 | 0 |
| 19282 | Hosneara Ahmed | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 04/05/19 | 04/04/22 | 0 | 0 |
| 19283 | Hsuan Hu | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 03/27/19 | 03/26/22 | 0 | 0 |
| 19284 | Jyi Sy Chiu | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 04/05/19 | 04/04/22 | 0 | 0 |
| 19285 | Mercedes Manning | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 04/19/19 | 04/18/22 | 0 | 0 |

| Contract | Contractor | Project Title | Start Term | End Term | South Coast AQMD $ | Project Total $ |
|---|---|---|---|---|---|---|
| Electric/Hybrid Technologies and Infrastructure (cont'd) | | | | | | |
| 19286 | Monica Sii | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 04/19/19 | 04/19/22 | 0 | 0 |
| 19287 | Quei-Wen P Yen | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 03/29/19 | 03/28/22 | 0 | 0 |
| 19288 | Rae Marie Johnson | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 04/05/19 | 04/04/22 | 0 | 0 |
| 19289 | Yilong Yang | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 04/09/19 | 04/08/22 | 0 | 0 |
| 19295 | Ivan Garcia | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 04/11/19 | 04/10/22 | 0 | 0 |
| 19296 | Jamei Kun | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 04/19/19 | 01/18/22 | 0 | 0 |
| 19297 | Laizheng Wei | Disburse Donated Mercedes-Benz USA, LLC Electric Vehicle Chargers | 04/19/19 | 04/18/22 | 0 | 0 |
| 19438 | Puente Hills Hyundai LLC | Lease Two 2019 Hyudai Kona EVs for Three Years | 06/06/19 | 06/05/22 | 61,156 | 61,156 |
| 20054 | Puente Hills Hyundai LLC | Lease One 2019 Hyundai Kona EV for Three Years | 08/23/19 | 08/22/22 | 29,640 | 29,640 |
| Fueling Infrastructure and Deployment (NG/RNG) | | | | | | |
| 12667 | West Covina Unified School District | Upgrade CNG Fueling Facility | 10/12/12 | 03/01/20 | 60,000 | 60,000 |
| 15541 | Foundation for California Community Colleges | Implement Enhanced Fleet Modernization Program | 05/07/15 | 04/01/20 | 21,270 | 30,000 |
| 16075 | City of Desert Hot Springs | Purchase One Heavy-Duty CNG-Powered Truck | 03/11/16 | 03/10/20 | 38,000 | 63,000 |
| 16244 | CR&R, Inc. | Renewable Natural Gas Production and Vehicle Demonstration Project | 09/03/16 | 03/02/20 | 900,000 | 55,000,000 |
| 17092 | Kore Infrastructure, LLC | Construct RNG Production Facility and Demonstrate RNG with Next Generation Natural Gas Engine | 10/14/16 | 10/13/21 | 2,500,000 | 25,500,000 |
| 18336 | ABC Unified School District | Replace Diesel School Buses with Near-Zero Emissions CNG Buses | 10/05/18 | 11/30/34 | 117,900 | 162,900 |
| 18337 | Alta Loma School District | Replace Diesel School Buses with Near-Zero Emissions CNG Buses | 10/05/18 | 11/30/34 | 78,600 | 108,600 |
| 18344 | Bellflower Unified School District | Replace Diesel School Buses with Near-Zero Emissions CNG Buses | 09/07/18 | 11/30/34 | 39,300 | 54,300 |
| 18346 | Chaffey Joint Union High School District | Replace Diesel School Buses with Near-Zero Emissions CNG Buses | 10/05/18 | 11/30/34 | 235,800 | 325,800 |

| Contract | Contractor | Project Title | Start Term | End Term | South Coast AQMD $ | Project Total $ |
|---|---|---|---|---|---|---|
| Fueling Infrastructure and Deployment (NG/RNG) (cont'd) | | | | | | |
| 18348 | Cypress School District | Replace Diesel School Buses with Near-Zero Emissions CNG Buses | 09/07/18 | 11/30/34 | 39,300 | 54,300 |
| 18349 | Downey Unified School District | Replace Diesel School Buses with Near-Zero Emissions CNG Buses | 09/14/18 | 11/30/34 | 157,200 | 217,200 |
| 18350 | Fountain Valley School District | Replace Diesel School Buses with Near-Zero Emissions CNG Buses | 09/07/18 | 11/30/34 | 39,300 | 54,300 |
| 18351 | Fullerton Joint Union High School District | Replace Diesel School Buses with Near-Zero Emissions CNG Buses | 10/05/18 | 11/30/34 | 157,200 | 217,200 |
| 18354 | Hemet Unified School District | Replace Diesel School Buses with Near-Zero Emissions CNG Buses | 10/05/18 | 11/30/34 | 196,500 | 271,500 |
| 18355 | Huntington Beach Union High School District | Replace Diesel School Buses with Near-Zero Emissions CNG Buses | 10/05/18 | 11/30/34 | 589,500 | 814,500 |
| 18363 | Orange Unified School District | Replace Diesel School Buses with Near-Zero Emissions CNG Buses | 09/14/18 | 11/30/34 | 39,300 | 54,300 |
| 18364 | Placentia-Yorba Linda Unified School District | Replace Diesel School Buses with Near-Zero Emissions CNG Buses | 10/05/18 | 11/30/34 | 235,800 | 325,800 |
| 18365 | Pupil Transportation Cooperative | Replace Diesel School Buses with Near-Zero Emissions CNG Buses | 10/05/18 | 11/30/34 | 235,800 | 325,800 |
| 18367 | Rialto Unified School District | Replace Diesel School Buses with Near-Zero Emissions CNG Buses | 10/05/18 | 11/30/34 | 510,900 | 705,700 |
| 18368 | Rim of the World Unified School District | Replace Diesel School Buses with Near-Zero Emissions CNG Buses | 10/05/18 | 11/30/34 | 117,900 | 162,900 |
| 18369 | Rowland Unified School District | Replace Diesel School Buses with Near-Zero Emissions CNG Buses | 11/02/18 | 11/30/34 | 117,900 | 162,900 |
| 18370 | San Jacinto Unified School District | Replace Diesel School Buses with Near-Zero Emissions CNG Buses | 09/14/18 | 11/30/34 | 78,600 | 108,600 |
| 18374 | Upland Unified School District | Replace Diesel School Buses with Near-Zero Emissions CNG Buses | 10/12/18 | 11/30/34 | 157,200 | 217,200 |
| Stationary Clean Fuels Technology | | | | | | |
| 13045 | ClearEdge (novated from UTC Power Corp.) | Energy Supply and Services Agreement to Install One 400 kW Phosphoric Acid Fuel Cell at South Coast AQMD Headquarters | 09/28/12 | 09/27/22 | 450,000 | 4,252,680 |
| Fuel/Emissions Studies | | | | | | |
| 15680 | National Renewable Energy Laboratory | ComZEV: Develop Detailed Technology and Economics-Based Assessment for Heavy-Duty Advanced Technology Development | 08/25/15 | 06/30/20 | 520,000 | 540,000 |

| Contract | Contractor | Project Title | Start Term | End Term | South Coast AQMD $ | Project Total $ |
|---|---|---|---|---|---|---|
| Fuel/Emissions Studies (cont'd) | | | | | | |
| 17245 | West Virginia University Research Corporation | Conduct In-Use Emissions Testing and Fuel Usage Profile on On-Road Heavy-Duty Vehicles | 06/09/17 | 02/28/20 | 1,625,000 | 1,625,000 |
| 17276 | University of California Riverside/CE-CERT | Develop ECO-ITS Strategies for Cargo Containers | 08/03/17 | 08/02/20 | 543,000 | 2,190,233 |
| 17277 | University of Southern California | Conduct Market Analysis for Zero Emission Heavy-Duty Trucks in Goods Movement | 11/03/17 | 02/28/20 | 350,000 | 524,000 |
| 17278 | University of Southern California | Develop Freight Loading Strategies for Zero Emissions Heavy-Duty Trucks in Goods Movement | 11/03/17 | 02/01/20 | 200,000 | 1,001,000 |
| 17286 | University of California Riverside/CE-CERT | Conduct In-Use Emissions Testing and Fuel Usage Profile on On-Road Heavy-Duty Vehicles | 06/09/17 | 02/28/20 | 1,625,000 | 1,625,000 |
| 17352 | California State University Maritime Academy | Develop and Demonstrate Vessel Performance Management Software and Vehicles | 06/09/17 | 06/08/21 | 50,086 | 195,195 |
| 18090 | University of California Riverside/CE-CERT | Study Secondary Organic Aerosol Formation from Heavy-Duty Diesel and Natural Gas Vehicles | 12/05/17 | 06/30/20 | 85,000 | 85,000 |
| 18206 | University of California Irvine | Assess Air Quality and Greenhouse Gas Impacts of a Microgrid-Based Electricity System | 04/06/18 | 04/05/20 | 660,000 | 1,300,000 |
| 19208 | University of California Riverside | Conduct Emission Study on Use of Alternative Diesel Blends in Off-Road Heavy Duty Engines | 06/21/19 | 04/30/20 | 261,000 | 1,353,499 |
| 20058 | University of California Riverside | Evaluate Meteorological Factors and Trends Contributing to Recent Poor Air Quality in Basin | 08/23/19 | 08/23/20 | 188,798 | 188,798 |
| Technology Assessment and Transfer/Outreach | | | | | | |
| 08210 | Sawyer Associates | Technical Assistance on Mobile Source Control Measures and Future Consultation on TAO Activities | 02/22/08 | 02/28/20 | 35,000 | 35,000 |
| 09252 | JWM Consulting Services | Technical Assistance with Review and Assessment of Advanced Technologies, Heavy-Duty Engines, and Conventional and Alternative Fuels | 12/20/08 | 06/30/20 | 30,000 | 30,000 |
| 12376 | University of California Riverside | Technical Assistance with Alternative Fuels, Biofuels, Emissions Testing and Zero-Emission Transportation Technology | 06/13/14 | 05/31/22 | 225,000 | 225,000 |
| 12453 | Tech Compass | Technical Assistance with Alternative Fuels, Fuel Cells, Emissions Analysis and Aftertreatment Technologies | 06/21/12 | 05/31/20 | 85,000 | 85,000 |

| Contract | Contractor | Project Title | Start Term | End Term | South Coast AQMD $ | Project Total $ |
|---|---|---|---|---|---|---|
| Technology Assessment and Transfer/Outreach (cont'd) | | | | | | |
| 15380 | ICF Resources LLC | Technical Assistance with Goods Movement, Alternative Fuels and Zero Emissions Transportation Technologies | 12/12/14 | 12/11/20 | 30,000 | 30,000 |
| 16262 | University of California Davis-Institute of Transportation Studies | Support Sustainable Transportation Energy Pathways (STEPs) | 01/05/18 | 01/04/22 | 240,000 | 5,520,000 |
| 17097 | Gladstein, Neandross & Associates, LLC | Technical Assistance with Alternative Fuels and Fueling Infrastructure, Emissions Analysis and On-Road Sources | 11/04/16 | 06/30/20 | 200,000 | 200,000 |
| 17358 | AEE Solutions, LLC | Technical Assistance with Heavy-Duty Vehicle Emissions Testing, Analysis and Engine Development | 06/09/17 | 05/31/21 | 200,000 | 200,000 |
| 19078 | Clean Fuel Connection Inc. | Technical Assistance with Alternative Fuels, EVs, Charging and Infrastructure, and Renewable Energy | 09/07/18 | 09/30/21 | 328,500 | 328,500 |
| 19227 | Gladstein, Neandross & Associates LLC | Technical Assistance with Alternative Fuels & Fueling Infrastructure, Emissions Analysis & On-Road Sources | 02/01/19 | 01/31/21 | 200,000 | 200,000 |
| 19302 | Hydrogen Ventures | Technical Assistance with Hydrogen Infrastructure and Related Projects | 04/24/19 | 04/23/21 | 50,000 | 50,000 |
| 20046 | RadTech International | Cosponsor the RadLaunch Program | 09/10/19 | 06/30/20 | 5,000 | 50,000 |
| 20085 | CALSTART Inc. | Technical Assistance for Development & Demonstration of Infrastructure and Mobile Source Applications | 11/8/2019 | 11/07/21 | 150,000 | 150,000 |
| 20098 | Coordinating Research Council, Inc. | Cosponsor the 30th Real World Emissions Workshop | 10/25/19 | 04/30/20 | 5,000 | 75,000 |
| 20104 | Gladstein, Neandross & Associates LLC | Cosponsor the 2020 Renewable Gas 360 Symposium | 11/01/19 | 02/28/20 | 25,000 | 175,000 |

# Appendix C

# Final Reports for 2019

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**South Coast AQMD Contract #19213** **December 2018**

# Participate in California Fuel Cell Partnership for CY 2018 and Provide Support for Regional Coordinator

## Contractor

Frontier Energy Inc.

## Cosponsors

7 Automakers
3 Energy companies
5 Public agencies
2 Technology companies
29 Associate members

## Project Officer

Lisa Mirisola

## Background

Established with eight members in 1999, the California Fuel Cell Partnership (CaFCP) is a collaboration in which private and public entities are independent participants. It is not a joint venture, legal partnership or unincorporated association. Therefore, each participant contracts with Frontier Energy (previously Bevilacqua-Knight, Inc./BKi) for their portion of CaFCP administration. South Coast AQMD joined the CaFCP in April 2000, and the CaFCP currently includes 48 organizations interested in furthering commercialization of fuel cell vehicle and fueling infrastructure technology.

## Project Objectives

Goals for 2018:

- Identify technology challenges and information gaps within the state's hydrogen station network
- Coordinate and collaborate on approaches to achieving 200 hydrogen stations in California
- Identify new concepts & approaches to initiate exponential station network growth
- Communicate progress of Fuel Cell Electric Vehicles (FCEVs) and hydrogen vehicles to current and new stakeholder audiences.
- Support two Fuel Cell Electric Bus Centers of Excellence (No. and So. Calif.)
- Increase awareness and market participation of fuel cell electric trucks, including supporting the deployment of funded pilot projects
- Coordinate nationally and internationally to share and align approaches

## Status

The members of the CaFCP intend to continue their cooperative efforts. This final report covers the South Coast AQMD for 2018 membership. This contract was completed on schedule.


**Figure 1: CaFCP LA County Fire Fighter Training, Los Angeles, CA in October 2018 including H2 delivery truck show-and-tell.**

## Technology Description

The CaFCP members together or individually are operating fuel cell passenger cars, transit buses, drayage trucks and associated fueling infrastructure in California. The passenger cars include Honda's Clarity, Hyundai's Tucson and Nexo, and Toyota's Mirai. The fuel cell transit buses include 13 placed at AC Transit, 15 at Sunline Transit, one with Orange County Transportation Authority and one with UC Irvine Student Transportation. It is expected that 22 more will be added by the end of 2019. Class 8 fuel cell drayage trucks include the Ballard powered BAE/Kenworth truck, the Hydrogenics fuel cell powered TransPower truck and Toyota's Portal Trucks.

## Results

Specific accomplishments include:

- 5,900 consumers and fleets have purchased or leased passenger FCEVs since entering commercial market in 2015;
- Transit agency members have 30 fuel cell electric buses currently in operation and more than 22 funded in 2018;

- There are 39 retail hydrogen fueling stations in operation in California and 25 in development.
- CaFCP staff and members continue to conduct targeted outreach and education in communities throughout California and provide information when requested to non-California requestors;
- CaFCP operates and maintains the Station Operational Status System (SOSS) that the 39 open retails hydrogen stations in the U.S. use to report status. This data, in turn, feeds real-time information (address, availability, etc.) to FCEV drivers through a CaFCP mobile website and several other apps and systems that support consumers.
- CaFCP actively engages in medium- & heavy-duty FCEV codes & standards coordination, specifically through sponsoring the Society of Automotive Engineers (SAE) J2600 (fueling connection) for inclusion of high-flow H35 fueling geometry for fuel cell electric bus (FCEB) fueling and fueling protocol standard development.
- CaFCP organized a Heavy-Duty H2 Infrastructure Industry Workshop on May 3 with the objective to develop the content for a Heavy-Duty Vehicle H2 Fueling Infrastructure fact sheet for decision maker education, to be published in 2019.
- Organized a February 2019 stakeholder workshop for input and structure of the 2019 FCEB Roadmap 2.0.

## Benefits

Compared to conventional vehicles, fuel cell vehicles offer zero smog-forming emissions, reduced water pollution from oil leaks, higher efficiency and much quieter and smoother operation. When renewable fuels are used as a source for hydrogen, fuel cell vehicles also encourage greater energy diversity and lower greenhouse gas emissions ($CO_2$).

By combining efforts, the CaFCP can accelerate and improve the commercialization process for all categories of vehicles: passenger, bus, truck, etc. The members have a shared vision about the potential of fuel cells as a practical solution to many of California's environmental issues and similar issues around the world. The CaFCP provides a unique forum where infrastructure, technical and interface challenges can be identified early, discussed, and potentially resolved through cooperative efforts.

## Project Costs

Auto members provide vehicles, and the staff and facilities to support them. Energy members engage in fueling infrastructure activities. The CaFCP's annual operating budget is about $1.15 million, and includes operating costs, program administration, joint studies and public outreach and education. Each full member makes an annual contribution of approximately $70,000 towards the common budget. Some government agencies contribute additional in-kind products and services. South Coast AQMD provides an additional $50,000 annually to support a Southern California Regional Coordinator. South Coast AQMD's additional contribution for 2018 medium- & heavy-duty FCEV codes and standards support was $125,000.

## Commercialization and Applications

While research by multiple entities will be needed to reduce the cost of fuel cells and improve fuel storage and infrastructure, the CaFCP has played a vital role in demonstrating fuel cell vehicle reliability and durability, fueling infrastructure and storage options and increasing public knowledge and acceptance of the vehicles and fueling.

CaFCP's goals relate to preparing for and supporting market launch through coordinated, individual and collective efforts. CaFCP members, individually or in groups:

- Prepare for larger-scale manufacturing, which encompasses cost reduction, supply chain and production.
- Reduce costs of station equipment, increase supply of renewable hydrogen at lower cost, and develop new retail station approaches.
- Support cost reduction through incentives and targeted research, development and demonstration projects.
- Continue research, development and demonstration of advanced concepts in renewable and other low-carbon hydrogen.
- Provide education and outreach to public and community stakeholders on the role of FCEVs and hydrogen in the evolution to electric drive.

In 2019, the primary goals are the same as the 2018 goals listed above, but can be expected to shift more towards heavy-duty vehicle application due to the adoption of regulation for transit bus fleets.

# Participate in California Fuel Cell Partnership for CY 2019 and Provide Support for Regional Coordinator

## Contractor

Frontier Energy Inc.

## Cosponsors

Automakers, energy companies, local, state and federal public agencies, technology companies, universities, transit agencies and others.

## Project Officer

Lisa Mirisola

## Background

Established with eight members in 1999, the California Fuel Cell Partnership (CaFCP) is a collaboration in which private and public entities are independent participants. It is not a joint venture, legal partnership or unincorporated association. Therefore, each participant contracts with Frontier Energy (previously Bevilacqua-Knight, Inc./BKi) for their portion of CaFCP administration. South Coast AQMD joined the CaFCP in April 2000. The CaFCP currently includes 17 executive members and 34 full and associate members with a focus on furthering commercialization of fuel cell vehicles, fueling infrastructure technologies and renewable and decarbonized hydrogen production.

## Project Objectives

The goals for 2019 include the following:

- Identify technology challenges and information gaps within the state's hydrogen station network
- Coordinate and collaborate on approaches to achieving 200 hydrogen stations in California
- Identify new concepts & approaches to initiate exponential station network growth
- Communicate progress of fuel cell electric vehicles (FCEVs) and hydrogen to current and new stakeholder audiences
- Increase awareness and market participation of fuel cell electric trucks and buses, including supporting the deployment of pilot projects
- Coordinate nationally and internationally to share and align approaches

## Status

The members of the CaFCP intend to continue their cooperative efforts. The final report covers the South Coast AQMD for 2019 membership. This contract was completed on schedule.

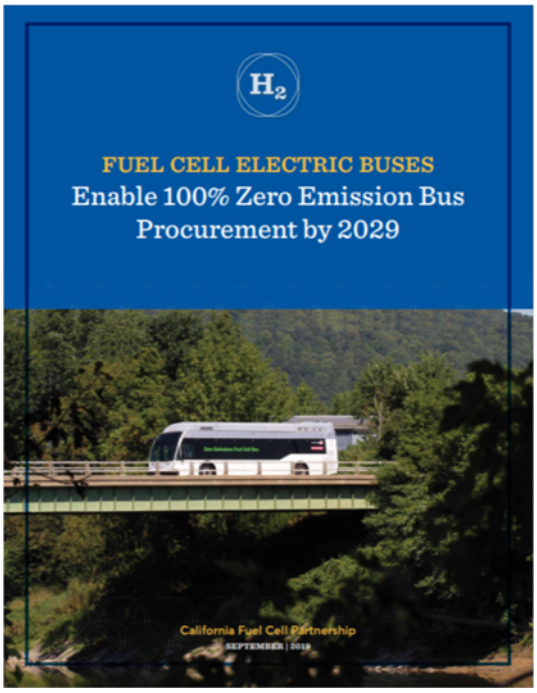



**Figure 1: CaFCP released its second fuel cell electric bus road, calling for 11 essential actions and setting new industry targets.**

## Technology Description

Many CaFCP members together or individually are operating fuel cell passenger cars, transit buses, drayage trucks and associated fueling infrastructure in California. Passenger cars include Honda's Clarity, Hyundai's Nexo and Toyota's Mirai. Fuel cell bus operators include AC Transit (16 buses), Sunline Transit (15), Orange County Transportation Authority (10) and UC Irvine Student Transportation (1), with 7 more expected in 2020. Class 8 fuel cell drayage trucks include a Ballard powered BAE/Kenworth truck, the Hydrogenics fuel cell powered TransPower truck and Toyota's Portal trucks.

## Results

Specific accomplishments include:

- Since 2015, 7,994 consumers and fleets have purchased or leased passenger FCEVs
- Transit agencies have 42 fuel cell electric buses in operation and more than 7 funded in 2019

- 40-plus light-duty retail hydrogen stations in operation in California and 20 in development; 4 bus stations in operation and 3 truck stations in development
- CaFCP staff and members continue to conduct targeted outreach and education in throughout California and provide information to non-California requestors
- CaFCP operates and maintains the Station Operational Status System (SOSS) that the 40-plus open retail hydrogen stations use to report status. This data, in turn, feeds real-time information (address, availability, etc.) to FCEV drivers through a CaFCP mobile website and other apps and systems. SOSS data also supports the new ZEV infrastructure credit in the Low Carbon Fuel Standard program
- CaFCP actively engages in medium- & heavy-duty FCEV codes & standards coordination, specifically through sponsoring SAE J2600 (fueling connection) for inclusion of high-flow H35 fueling geometry for fuel cell electric bus (FCEB) fueling and fueling protocol standard development
- Published the 2019 FCEB Roadmap 2.0, *Fuel Cell Electric Buses Enable 100% Zero Emission Bus Procurement by 2029*

## Benefits

Compared to conventional vehicles, fuel cell vehicles offer zero smog-forming emissions, reduced water pollution from oil leaks, higher efficiency and much quieter and smoother operation. When renewable fuels and electricity are used as a source for hydrogen, fuel cell vehicles also encourage greater energy diversity and lower greenhouse gas emissions ($CO_2$).

By combining efforts, the CaFCP can accelerate and improve the commercialization process for all categories of vehicles: passenger, bus, truck, etc. The members have a shared vision about the potential of fuel cells as a practical solution to many of California's environmental issues and similar issues around the world. The CaFCP provides a unique forum where infrastructure, technical and interface challenges can be identified early, discussed, and potentially resolved through cooperative efforts.

## Project Costs

Auto members provide vehicles, and the staff and facilities to support them. Energy members engage in fueling infrastructure activities, including hydrogen production. CaFCP's annual operating budget is about $1.15 million, and includes operating costs, program administration, joint studies and public outreach and education. Each executive member makes an annual contribution of approximately $70,000 towards the common budget. Some government agencies contribute additional in-kind products and services. South Coast AQMD provides an additional $50,000 annually to support a Southern California Regional Coordinator.

## Commercialization and Applications

Research and scaling of technology by multiple entities will be needed to reduce the cost of fuel cells and improve fuel storage and infrastructure. CaFCP has played a vital role in demonstrating fuel cell vehicle reliability and durability, fueling infrastructure and storage options and increasing public knowledge and acceptance of the vehicles and fueling.

CaFCP's goals relate to preparing for and supporting market launch through coordinated individual and collective effort. CaFCP members, individually or in groups:

- Prepare for larger-scale manufacturing, which encompasses cost reduction, supply chain and production
- Reduce costs of station equipment, increase supply of renewable hydrogen at lower cost, and develop new retail station approaches
- Support cost reduction through incentives and targeted research, development and demonstration projects
- Continue research, development and demonstration of advanced concepts in renewable and other low-carbon hydrogen
- Provide education and outreach to public and community stakeholders on the role of FCEVs and hydrogen in the evolution to electric drive

In 2020, the primary goals are the same as the 2019 goals listed above but can be expected to shift more towards heavy-duty vehicle application due to the adoption of regulation for transit bus fleets and the proposed Advanced Clean Truck regulation being considered in 2020.

**South Coast AQMD Contract #08063** **January 2019**

# Develop & Demonstrate Twenty Plug-In Hybrid Electric Vehicles

## Contractor

Quantum Fuel Systems LLC (formerly Quantum Technologies Worldwide, Inc.)

## Cosponsors

South Coast Air Quality Management District

## Project Officer

Lisa Mirisola

## Background

Since hybrid electric passenger vehicle prototypes have been converted to plug-in hybrids, there has been increasing support for PHEVs from a wide array of organizations, including electric utilities, environmental groups, energy independence organizations, and other air districts. Several automobile manufacturers announced plans to investigate the technology, but voice concerns about the battery durability in terms of calendar and cycle life.

## Project Objective

At its November 3, 2006 meeting, the Governing Board approved RFP #P2007-14 to design, engineer, convert, test, certify, demonstrate, and maintain for 60 months 30 plug-in hybrid electric vehicles with supporting infrastructure at up to 15 demonstration sites in the South Coast Air Basin. At the March 2, 2007 meeting, the Governing Board awarded funding to Quantum to convert twenty new Ford Escape Hybrid vehicles to plug-in hybrid electric vehicles (PHEVs) using lithium-ion battery systems and controls.

## Technology Description

Similar to commercially available hybrid-electric vehicles, PHEVs utilize a battery pack and an electric motor in concert with an internal combustion engine. PHEVs, however, can employ a larger battery pack which can be designed to extend the electric portion of the driving cycle, providing improved fuel economy, lower greenhouse gas emissions, and reduced petroleum dependence. The larger battery pack must be fully recharged external to the vehicle so a charger, plug, and energy management system must be integrated into the vehicle. This design is an example of a blended strategy that provides electric range in limited, low power demand situations, but not miles of dedicated all electric range now available from major automakers.

## Status

The battery pack supplier was changed from ALP in the original proposal to EnerDel for this conversion to a 11 kWh lithium-ion replacement for the Ford NiMH hybrid battery. After the first six vehicles were converted and crash-tested, twenty converted plug-in hybrids were delivered to South Coast AQMD in 2010 under CARB EO B-55.

**Figure 1: Enerdell battery integrated by Quantum Technologies**

Originally, the demonstration period was set for five years, but the project was extended to January 31, 2019 to provide ongoing support for maintenance and operation in the South Coast AQMD fleet. As of July 2018, the 20 vehicles accumulated over a million miles, with three vehicles over 100,000 miles each. Eighteen of the vehicles are still in operation as PHEVs in the

South Coast AQMD fleet. One vehicle was scrapped in 2018 after an accident, and one was returned to stock Ford Escape Hybrid configuration in 2018.

## Results

This was the first aftermarket plug-in hybrid certified by CARB using newly adopted procedures for low volume manufacturers.

Ten of the vehicles were initially wrapped and used primarily for outreach purposes. Although some cities were interested in operating the vehicles, plug-in hybrids started to become available from major automakers, so the funds originally identified for adding infrastructure at fleets in the South Coast region were redirected to provide ongoing support to the vehicles used in the South Coast AQMD fleet.

In 2010, The Society of Automotive Engineers (SAE) revised Recommended Practice J1772 for charging vehicles. The cost to convert the connector for the Quantum Escape PHEVs was evaluated and determined to be cost prohibitive.


**Figure 2: Quantum PHEV wrapped for outreach & education**

## Benefits

The Quantum converted plug-in hybrid's greatest value was as outreach tools to begin to educate the public and show the potential for plug-in hybrids before commercial plug-in hybrids were introduced in December 2010 by General Motors (Chevrolet Volt) and Toyota (Prius PHV).

One of the Quantum PHEVs has accumulated about 4,000 miles in test routes while operating as a mobile platform for the South Coast AQMD's Air Quality Spec program.

**Figure 3: Quantum PHEV operated as mobile platform for South Coast AQMD Air Quality Spec. program**

## Project Costs

The price of the 2010 Ford Escape Hybrid vehicles with navigation/energy flow displays prior to conversion increased by $70,000 for twenty vehicles since the original proposal was submitted in 2007. The total cost for this project was $2,885,266 with South Coast AQMD cost share not to exceed $2,165,613. Funds unspent were $9,133.

## Commercialization and Applications

During the term of this contract, plug-in hybrid electric passenger vehicles have been commercialized by Ford, General Motors, Toyota, and many other automakers. The business case for aftermarket conversion of hybrid passenger vehicles to plug-in hybrid is not currently attractive for additional investment or commercialization, and the market for medium and heavy-duty vehicles is still developing.

**South Coast AQMD Contract #13058** **December 2019**

# Develop Microturbine Series Hybrid System for Class 7 Heavy-Duty Vehicle Applications

## Contractor
Capstone Turbine Corp.

## Cosponsors
Kenworth Truck Company
San Joaquin Valley APCD (SJVAPCD)

## Project Officer
Phil Barroca

## Background
Medium and heavy-duty diesel delivery trucks are a significant source of particulate matter and NOx emissions. Due to serous health concerns, it is especially important to reduce these criteria pollutants in heavily populated urban areas where such delivery trucks normally operate. The State of California, the US Environmental Protection Agency (EPA), and many countries around the world are also seeking ways to mitigate climate change by reducing greenhouse gas emissions such as $CO_2$. To support these concerns, South Coast AQMD, SJVAPCD, the California Air Resources Board (CARB), EPA, the Department of Energy, and others are providing funds for development and demonstration of new technologies that offer the potential to both reduce criteria pollutant and greenhouse gas emissions, while simultaneously decreasing operating costs in order to make these new technologies economically viable. The subject project is aimed at addressing these issues using a refrigerated box body Class 7 truck where emissions and fuel costs include both the drivetrain as well as the refrigeration unit.

## Project Objective
The overall objective for the Class 7 Hybrid Truck project is to demonstrate the performance and quantify the emissions and fossil fuel displacement potential of an initial prototype when operating in a real commercial application in the South Coast Air Basin.

## Technology Description
The electric drive system consists of two permanent magnet electric motors, each capable of 150 horse power output. They are connected on a common shaft driving an Eaton Ultrashift transmission. Gear ratios have been preselected to optimize the characteristics of the electric drive automatic shifting. The electric motors receive power from a 47kWh Lithium-Ion battery pack at a nominal 622Vdc. The battery energy storage capacity provides about a 10 to 20-mile range on its own, depending on drive cycle characteristics. A Level II onboard battery charging system is included with a standard J1772 connection. Accessory drives are all electric, including power steering, air conditioning, and a Bendix air brake compressor.

**Figure 1: Hybrid Kenworth Class 7 Reefer truck with CNG powered Capstone turbine**

A 65kW Capstone microturbine operating on compressed natural gas serves as an on-board battery charger, or range extender. Fuel is provided from an Agility behind-the-cab 61 diesel-gallon-equivalent compressed natural gas storage system and includes both regular fill and fast fill connections. Depending on the drive cycle, operating range can be extended to more than 200 miles. The microturbine outputs direct connection (dc) directly to the battery system. The vehicle controller automatically switches the microturbine on and off and adjusts power demand, depending on the battery state of charge. Microturbine exhaust exists through a diffuser under the chassis and behind the cab. Exhaust emissions are extremely clean, and the microturbine is CARB certified.

The refrigerated box body is a 24-foot Supreme Kold King insulated model. The refrigeration unit is a Carrier Supra 860 with Transicold controller. The Carrier unit includes a diesel engine but is intended for the demonstration project to operate on the highway

using the standby electrical connection to an inverter powered from the hybrid's 622Vdc battery pack.

## Status

The prototype Class 7 Hybrid Truck was built and successfully operated on the PACCAR Technical Center test track as well as actual on-road city and highway routes. Representative drive cycles were defined for the potential demonstration partners. Using these drive cycles, emissions and fuel economy testing was completed on a chassis dynamometer at UC Riverside on the prototype hybrid truck as well as a comparable Class 7 diesel truck. Unanticipated development effort and reliability issues related to the batteries, the on-board battery charger, the air brake compressor, and the 600V class drive motors caused project delays, which resulted in a decision not to extend the project into the customer demonstration phase. However, none of these issues are insurmountable barriers to achieving a successful future commercial product.

## Results

The three representative drive cycles include both urban and rural delivery routes, details of which are summarized in the Task 2 Report - Define Customer Use Profile and Requirements. UC Riverside measured criteria pollutant and fuel consumption of both the Class 7 hybrid and a comparable traditional diesel. The hybrid truck successfully completed all three drive cycles, with the microturbine range extender able to avoid depleting the high voltage batteries' state-of-charge.

Emissions of the refrigeration unit operating on its integrated diesel engine were also characterized and are included in the overall operating comparison with traditional technology.

Figure 2 provides two graphs comparing NOx and fuel cost for one of the representative drive cycles. Details are provided in the Task 5 Track Test and Analysis Final Report. It should be noted that the NOx emissions for the microturbine range extender are actually less than what the EPA reports for the clean California grid when used to charge the batteries, so the NOx graph comparison only includes the tailpipe emissions from the Capstone microturbine.

$CO_2$ emissions comparisons included the benefit of electric utility charging, resulting in up to 30% well-to-wheels reduction for the hybrid.

Performance results are in line with predictions made using a simple hybrid vehicle simulation model.

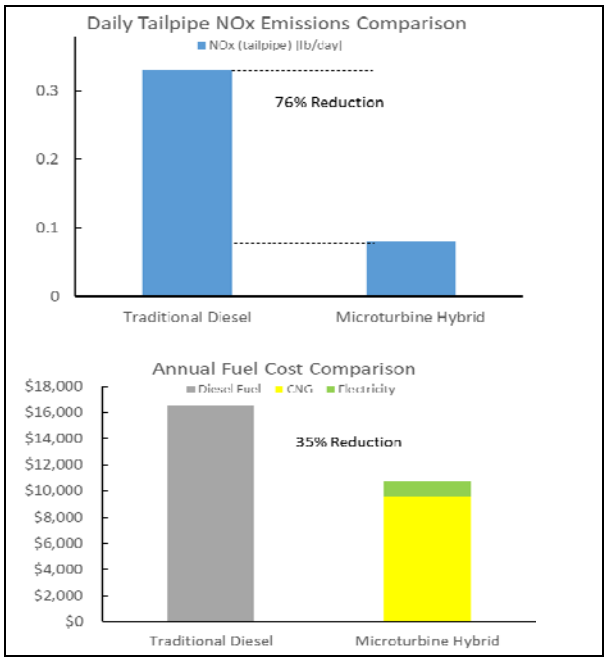



**Figure 2: NOx Tailpipe and Fuel-Cost Comparisons**

## Benefits

The benefits of the hybrid system clearly show both significant reductions in criteria and greenhouse gas emissions, as well as reduced fuel costs.

## Project Costs

Total project costs were estimated at $850,000, with $360,000 in funding awarded from the South Coast AQMD. Project costs were shared with the San Joaquin Valley APCD, with a significant cost-share from Capstone and Kenworth. South Coast AQMD actual funding is expected not to exceed $300,000 as Tasks 6 and 7 were not completed under this contract after all.

## Commercialization and Applications

The benefits noted above include significant operating cost savings for potential truck operators. However, the initial capital cost of electrifying a truck remain substantially more than traditional drivetrains. Battery life and replacement costs are also not yet well understood. The current increase in electric vehicle sales should both decrease costs as well as provide actual long-term field experience to better estimate battery life.

Cost projections at sales volumes of 10,000 hybrid trucks per year indicate a reasonable payback time of less than five years, making this technology a potentially viable option in the future.

**South Coast AQMD Contract #14222** **July 2019**

# Develop and Demonstrate Plug-In Hybrid Electric Retrofit System for Class 6 to 8 Trucks

**Contractor**
Odyne Systems LLC

**Cosponsors**
California Energy Commission (CEC)
Department of Energy (DOE)
Odyne Systems LLC

**Project Officer**
Seungbum Ha

## Background

Odyne Systems, LLC, has become a leading designer and manufacturer of parallel plug-in hybrid electric vehicle systems for the commercial truck market. The project was proposed, in conjunction with a $1.2M California Energy Commission (CEC) grant to retrofit 5 vehicles in the State of California with the Odyne hybrid system (CEC Agreement ARV-11-013). Design duty cycle and component sizing is derived from the 119 vehicle telematics data which are the results of the 2013-2015 South Coast AQMD, Department of Energy (DOE) and Electric Power Research Institute (EPRI) deployment project (South Coast AQMD 10659)

## Project Objective

The project objectives were to design, develop and retrofit one medium or heavy-duty plug-in hybrid vehicle (PHEV) work truck with extended stationary engine-off technology and to qualify improvements in fuel economy and emissions through prototype tests and deployment within the South Coast Air Quality Management District.
The focus of the retrofit design activity will be to evaluate commercially available smaller and lower cost component alternatives and system solutions which will meet the performance requirements of the customer in a smaller and easier to retrofit package.

## Technology Description

The Odyne Plug-in Hybrid system incorporates a novel approach in connecting the hybrid drive train to the vehicle offering idle reduction, regenerative braking, launch assist, climate control, and exportable power. Odyne's unique, modular design interfaces seamlessly with a vehicle's transmission and can be installed on a wide range of chassis, powertrains and work truck applications. The minimally intrusive design provides both hybrid driving functionality and jobsite anti-idle electrification without significant redesign of the existing vehicle platforms.

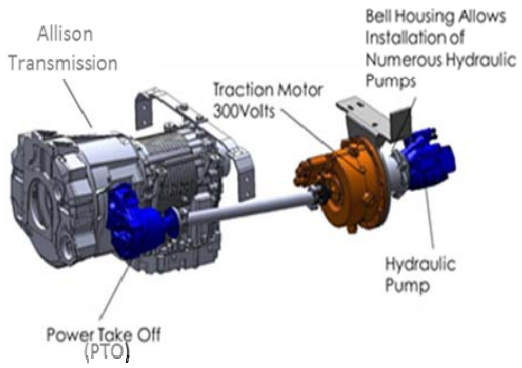



**Figure 1: Odyne PHEV Powertrain**

## Status

The project was completed in June 2019. The final report detailing vehicle demonstration and evaluation was submitted in August 2019. The demonstration vehicle, deployed at Southern California Edison (SCE), remains in daily use within the utility fleet.

The Odyne Plug-in Hybrid and ePTO system developed in this project was released for commercial sale and was approved for the California Air Resource Board HVIP voucher program in 2019. Odyne is continuing to work with suppliers on reducing component costs and

working with supporting agencies to initiate projects to increase the driving and full day fuel and emissions savings in order to continue to improve the customer value and return on investment.

## Results

Based on telematics results from the 2013 119 vehicle deployment project, Odyne was able to downsize the specification for the hybrid motor, traction inverter, and battery and create a next generation, lower cost product for development and test. Full functional design validation was competed to verify performance. The testing demonstrated the capability to power equipment requiring up to 16 kW (21 HP), export 120/240V power up to 6 kW, support 12V vehicle loads up to 1.2 kW and provide 16,000 BTU of cabin heat or air conditioning.

SCE was identified as the utility willing to participate in this program. The vehicle selected by SCE was a 2014 International 4300 with an Altec TA-60 Aerial Bucket obtained from the existing SCE fleet. Odyne contracted Valley Power, an Ontario, CA company, to perform the retrofit installation of the prototype hybrid system

Telematics systems were utilized to determine the real-world duty cycles for the deployment vehicle. The SCE vehicle is utilized within medium range to the fleet base for a utility vehicle with an average daily distance of approximately 25 miles and an average speed of just over 17 MPH. At the job site, the SCE unit averaged 4.48 ePTO hours over the course of the evaluation period.

Emissions testing was performed at the UC Riverside College of Engineering-Center for Environmental Research and Technology (CE-CERT) facility. Results applied to the vehicle duty cycles determined by telematics analysis yielded the average savings displayed in Table 1.

| SCE Avg. Full Day Emissions (25.6 Miles, 4.28 hour ePTO) | | | | |
|---|---|---|---|---|
| | CO2 | NOx | Fuel | Grid Energy |
| | g | g | gal | kWh |
| Conventional | 94844 | 134.0 | 9.553 | 0.00 |
| Hybrid | 38630 | 39.4 | 3.890 | 8.98 |
| Hybrid Change | -59% | -71% | -59% | X |

**Table 1. Demonstration vehicle average daily fuel and emissions savings**

## Benefits

The results of the Telematics data and Full Cycle Emissions Analysis demonstrates that the Odyne Plug-in Hybrid system deployed in this project can achieve fuel use and greenhouse gas (GHG) emissions reductions of 58% and NOx emission reductions of 71% when compared to a similarly equipped conventionally fueled vehicle. Annual operational costs are predicted to be reduced by $6,733. A full cycle (Wells-to-Wheels) analysis of the emissions results utilizing the California Greenhouse Gases, Regulated Emissions and Energy Use in Transportation (CA-GREET) 2.0 model information with the duty cycles identified demonstrated that the inclusion of.

## Costs

Pending completion of the final report and final report milestone payment, the project will have been completed at the proposed cost to South Coast AQMD of $389,000. The CEC cost sharing project ARV-11-013 was completed at a final contribution of $1,185,000. The Department of Energy cost sharing project DE-EE0001077/AQMD 10659 was completed at a final contribution of $13,790,958. Odyne Project expenses totaled $1,123,970.

## Commercialization and Applications

The Odyne system developed in this project was released for commercial sale as the G2V3 Odyne Plug-in Hybrid and ePTO systems. The testing and field demonstration proved that a single, 14 kWh battery and smaller power electronics were suitable for medium sized aerial devices which allowed Odyne to reduce the base system cost to utility customers by over $10,000.

Based, in part, on the testing performed in this project, the Odyne Plug-In Hybrid system was approved for the California Air Resource Board Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) in 2019. Odyne is continuing to work with suppliers on reducing component costs and working with supporting agencies to initiate projects to increase the driving and full day fuel and emissions savings to continue to improve the customer value and return on investment.

**South Coast AQMD Contract #14256** **May 2019**

# Develop & Demonstrate Vehicle-to-Grid Technology

## Contractor
National Strategies, LLC

## Cosponsors
California Energy Commission
NRG Energy
Torrance Unified School District

## Project Officer
Joseph Impullitti/Mei Wang

## Background
Electric vehicle (EV) school buses are on the horizon, but there is a reluctance by the original equipment manufacturers (OEMs) to develop them due to the high capital costs of acquisition to school districts/operators when compared to fossil fuel school buses. Finding a path to cost parity between EV and fossil fuel school buses is a critical step in encouraging school districts to move towards the use of cleaner running buses.

## Project Objective
The Vehicle-to-Grid (V2G) Electric School Bus Demonstration Project sought to demonstrate that V2G capable school buses can overcome the capital cost barriers associated with EV technology and be financially viable on a total cost-of-ownership basis. The project plan was to retrofit two 1996 Type C diesel school buses with Transportation Power, Inc.'s (TransPower) "ElecTruck™" drive system coupled with V2G hardware, software and charging infrastructure. The two buses were to be demonstrated in actual service with Torrance Unified School District (TUSD).

## Technology Description
The technology is a battery-electric drive system that uses a low-cost electric motor coupled to an automated manual transmission, a large pack of prismatic lithium iron phosphate batteries, and advanced controls.

## Status
The project was completed on April 30, 2019, and the full report has been filed with South Coast AQMD. The major elements included fully integrating the 1996 school buses with the TransPower "ElecTruck™" drive system, the commissioning/testing of the school buses, and passing inspection by the California Highway Patrol (CHP), so that the EV school buses could safety operate for pupil transportation. While the development of the EV school buses was conducted, the team initiated the design and installation of the EV charging system that would allow for V2G operations. This process included the completion of an interconnection agreement with Southern California Edison (SCE). Notably, this was the first such agreement for an EV school bus in the world. With the EV school buses completed and the charging system installed, the EV school buses began student transportation at TUSD in September 2016. V2G operation was initiated in March 2019.

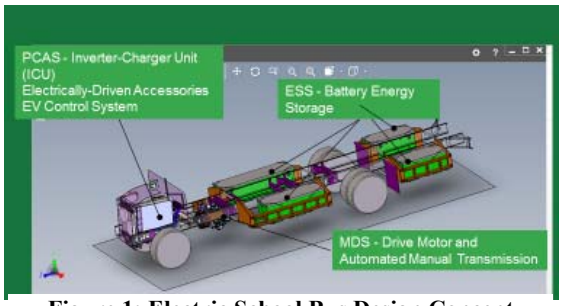



**Figure 1: Electric School Bus Design Concept**

## Results
This project was able to show that the technology does exist to meet the 80 miles per day national average range requirements of the student transportation industry. The project was also able to pass all CHP requirements for school bus safety. It also proved that a charging infrastructure could be installed that would allow for V2G operations and a successful interconnection agreement with the local utility could be completed. Most importantly, the project delineated a clear path for EV school buses to reach total cost of ownership (parity with fossil fuel school buses, meaning the reality of zero emission vehicle (ZEV) student transportation is at hand.

It should be noted that the larger stakeholder group associated with the project, from the school bus drivers to the California Independent System

Operator, all confirmed the positive benefits of EV school buses with V2G.

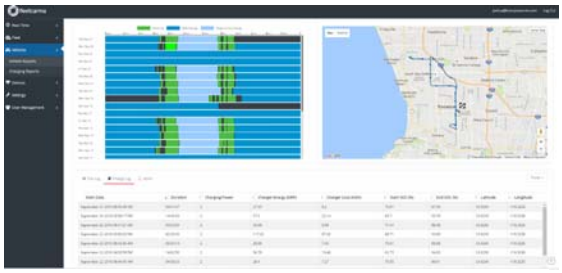


**Figure 2: Fleet Carma Data from Recent Operation of V2G School Bus in Service at TUSD. Horizontal bar chart shows green for morning & afternoon driving in service, light blue is mid-day charge, dark blue is overnight charge.**

Several issues did come up stemming from both the decision to retrofit existing 20-year-old school buses and the reluctance of the OEM to provide robust support to the effort. While the age of the buses and the act of retrofitting were not the only source of challenges, they did create significant delays and exacerbate reliability issues. Therefore, while the retrofit model cannot be recommended based on this project, it still resulted in lessons learned toward technical feasibility.

It should be noted that being the first school bus V2G project led to significant delays on the interconnection agreement with SCE. This further delayed the project due to California Public Utility Commission rule interpretations. However, the team and SCE worked together to eventually achieve an interconnection agreement that did result in energy savings for TUSD, reducing total cost of ownership impacts for TUSD.

The estimated future cost of converting school buses to electric is $200,000-$300,000, depending on purchase volume and other variables.

## Benefits

The project benefits are significant across the region. The team was able to show that ZEV student transportation is both technically and financially viable for nearly all school bus routes in South Coast AQMD. While replacing only two school buses at TUSD with EV V2G units had negligible emission reductions when compared to the total fleet, the project still was able to successfully demonstrate the potential of ZEV student transportation and provide a path forward. In reducing the use of fossil fuel transportation for young children, whose lungs are still developing, the benefits go far beyond the economic benefits to school districts.

The project was also able to fully demonstrate the viability of V2G for EV school buses. Though the data is limited, it did show potential savings of $6,000 per year per bus in energy cost avoidance for TUSD. The $6,000 is a "net" figure, considering all the energy consumption associated with the EV school buses. While it includes the savings from switching from petroleum fuel to electricity, it should be noted that these savings would be much diminished without the electric-bill-management effect provided by V2G. That the V2G operations were limited to "behind the meter" operation suggests that even more "upside" could be realized from EV school bus V2G operations.

## Project Costs

The total project costs, including the two buses converted for TUSD and four others funded by the CEC, was $3.8 million, consistent with initial estimates. The project funding partners were: South Coast AQMD-$250,000; California Energy Commission-$1,473,488; and National Strategies-$1,654,201.

## Commercialization and Applications

From a commercialization and application perspective, the project was very successful. Prior to awarding the funds to the project team, there was not a single EV school bus in operation in California. Further, there were no school bus OEMs providing EV school buses in the market. As this project moved forward and early results were positive, the EV school bus market changed markedly. All three major school bus OEMs and a few smaller ones announced plans to produce EV school buses, most with some form of V2G technology. Further, by project end, there were approximately 75 EV school bus operating in the state with a significant number on order with OEMs that would likely double that number by year's end.

Further, this project led to the realization that V2G was not a theory but a reality. Based on the initial results of this project, the South Coast AQMD and the U.S. Department of Energy awarded Blue Bird Corporation a $10 million grant that will result in the first commercially available U.S.-manufactured EV V2G school bus that can be deployed in all 50 states. Most participants in this project are also involved in the Blue Bird project. Therefore, this project initiated the path for full EV V2G school bus commercialization.

**South Coast AQMD Contract #18072** **June 2019**

# Study Electrification Options of Energy Services for EJ Communities and Non-Attainment Areas


## Contractor

Electric Power Research Institute (EPRI)
Ramboll

## Cosponsors

California Energy Commission (CEC)
Electric Power Research Institute (EPRI)

## Project Officer

Patricia Kwon


## Background

This study analyzes the potential for electric appliances such as furnaces and heat pumps, as well as electric vehicles to provide air quality and health effects benefits for residents in environmental justice (EJ) communities. Combined with residential solar and wind generation, electrification is a key strategy for achieving greenhouse gas emission reduction targets. However, the effects of electrification on air quality are less clear. This study is an extension of previous work looking at the benefits of electrification on air quality.

## Project Objective

Electric Power Research Institute (EPRI) conducted a statewide analysis of the economic and environmental attributes of electrification. The analysis focused on the costs and benefits of electrification technologies on residents in EJ communities.

## Technology Description

Air quality models analyzed the effects of existing electrification technologies deployed at a larger scale. Assumptions for the potential for electrification are primarily from the study *Long Term Energy Scenarios in California* (EPC 14-069, Mahone et al, 2018[1]). The Mahone et al study investigated potential pathways to achieve California's greenhouse gas (GHG) emissions goals. The "in-state biomass" scenario was used since it emphasized various electrification strategies. Additional assumptions were necessary since many emissions sources affecting air quality are not included in GHG models. Electrification includes a broad array of technologies for transitioning direct fossil fuel use to electricity. Examples of electrification technologies include batteries and motors for electrification of transportation, heat pumps for electrification of space and water heating, and technologies for industrial electrification. Air quality modeling and a health effects analysis was performed based on levels of electrification from different sources. Air quality modeling extended the current emissions inventories to the year 2050 and looked specifically at the effects of electrification on pollutant levels in future years, and health effects stemming from pollutant levels in future model years.

## Benefits

Precise costs for electrification are difficult to estimate due to the variety of factors that affect lifetime costs, but cost estimates show that the air quality benefits are much greater than costs and are "paid back" in a few years. Monetized health benefits from reduced ozone and PM2.5 were estimated at $108 billion for the state of California in 2050, including $56 billion in benefits for the South Coast Air Basin. The improvements in air quality were used in a health impacts model to calculate the monetized benefits as shown in the table below.

| Pollutant | Avoided mortalities | Valuation |
|---|---|---|
| $PM_{2.5}$ | 6,242 | $54.3B |
| Ozone | 179 | $1.6B |
| **Total** | **6,421** | **$55.9B** |

**Table 1: Pathways Model. CEC Publication Number CEC-500-2018-012**

[1] *Mahone, A., Subin, Z., Kahn-Lang, J., Allen, D., Li, V. De Moor, G., Ryan, N., Price, S. Deep Decarbonization in a High Renewables Future: Updated Results from the California.*

Figure 1 shows the monetized health benefit of electrification within the South Coast Basin, by census tract.

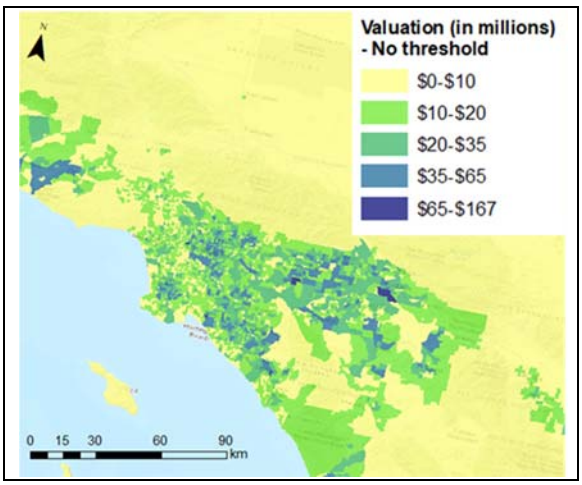



**Figure 1: Monetized Health Benefits of Electrification within South Coast Basin by Census Tract**

## Results

In 2050, the study shows summer average maximum daily 8-hour ozone below 65 parts per billion (ppb) in the South Coast Air Basin, with ozone reductions exceeding 5 ppb in most of the South Coast Air Basin and as much as 10 ppb. In 2050, PM2.5 would be reduced by 2 µg/m$^3$ and up to 14 2 µg/m$^3$ in most of the South Coast Air Basin due to electrification. In addition, the study showed that electrification would significantly reduce mortality rates in EJ communities.

Recommendations are to identify strategies to provide funding for the cost of electrical infrastructure upgrades for homes of low-income residents in EJ communities due to the high cost of retrofits in existing homes.

## Project Costs

Total project cost is $1,558.657, with funding provided by CEC ($799,444), EPRI ($609,213), and South Coast AQMD ($150,000).

## Commercialization and Applications

Electrification technologies such as electric vehicles and heat pumps are commercially available but are generally more expensive than conventional options. Incentivizing these technologies is necessary to cover the differential cost.

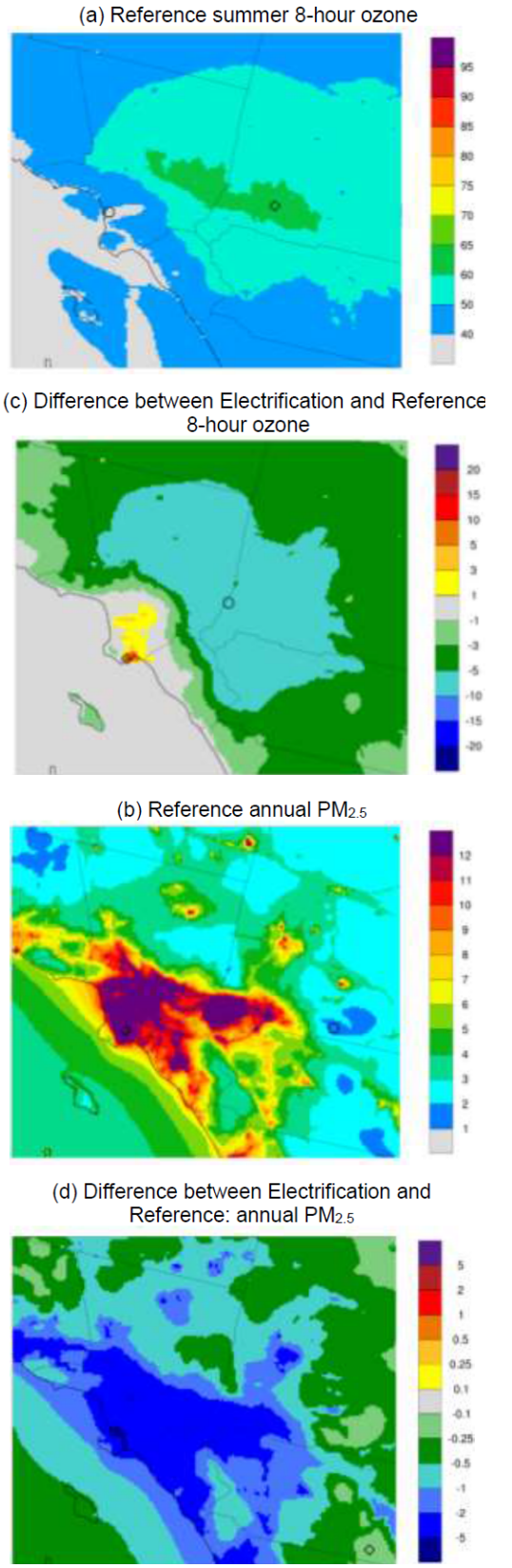



**Figure 2: Electrification Effects for Summer Max Daily Average 8-Hour Ozone and Max Annual PM2.5**

**SCAQMD Contract #16076** **November 2019**

# Purchase & Deploy One Heavy-Duty CNG Paratransit Vehicle

## Contractor
Coachella Valley Association of Governments (CVAG)

## Cosponsors
South Coast AQMD

## Project Officer
Phil Barroca

## Background
In 2015, the Coachella Valley Association of Governments (CVAG) Homelessness Committee identified homeless services as a significant community need. The first comprehensive center for homeless services in western Coachella Valley was built to provide shelter, training, and services to help homeless individuals work to regain self-sufficiency. The facility is located in an area where public transportation is not available, making it difficult for homeless people to get to and from the center. The existing shuttle buses in use were getting older and in constant need of repair. This project replaced an older, higher emitting shuttle bus with a vehicle using cleaner more advanced technology.

## Project Objective
The South Coast AQMD Board approved funding for CVAG to purchase a heavy-duty CNG paratransit vehicle to ensure that a clean vehicle would be used to transport homeless people to access services and shelter. To maximize accessibility, the vehicle will have a wheelchair lift and meet Americans with Disabilities Act (ADA) requirements. The Air Quality Management Plan relies on accelerated implementation of advanced technologies within Southern California to achieve federal and state ambient air quality standards and further reductions in air toxic exposure. Conversion of high mileage gasoline or diesel-powered vehicles to natural gas-powered vehicles can significantly reduce criteria pollutants, greenhouse gas emissions, and use of petroleum-based fuel. This vehicle will help South Coast AQMD meet the goals of the Air Quality Management Plan.

## Technology Description
One heavy-duty dedicated compressed natural gas-powered paratransit vehicle will be used to shuttle homeless people throughout Coachella Valley. The vehicle purchased was a Class E, 32 foot, Ford F-550 powered by a 6.8L V-10 gasoline engine. This engine was converted to dedicated CNG power using a CARB-certified conversion system. The vehicle also has wheelchair lift capability and meets ADA requirements. The bus has a 28-person capacity.

This project replaced a 2007 diesel-powered Ford F450 Econoline van with over 165,000 miles on it. This older, higher emitting shuttle bus was decommissioned and dismantled as part of this project.

**Figure 1: Compressed natural gas (CNG) powered paratransit shuttle bus.**

## Status
The vehicle was deployed in September 2016, primarily for use transporting clients to and from Roy's Desert Resource Center located north of Palm Springs. In July 2017, this emergency shelter was repurposed as a long-term board and care facility operated by the Riverside University Health System. Upon closure of Roy's, CVAG entered into a contract with Path of Life Ministries to operate the West Valley Navigation Center program following a competitive bid process. In

late 2017, the scope of the program expanded to address homelessness throughout all of Coachella Valley, and the program was renamed 'CV Housing First.'

Operation of the vehicle was transferred to this new program operator in anticipation of the need to provide similar shuttle services for homeless individuals. However, the new program adopted a 'housing first' model, which provides low barrier access to housing as quickly as possible, thereby reducing reliance on emergency shelter. This meant a reduced need to shuttle homeless people to and from a mass shelter every day.

In July 2019, Path of Life Ministries notified CVAG that they no longer needed to use the shuttle as part of the regional homelessness program and the bus was returned. CVAG is currently evaluating options for future use of the vehicle in efforts to address regional homelessness.

The CNG van was driven 31,100 miles during the term of this project. Most of these miles were driven to and from Roy's Desert Resource Center to various locations throughout Coachella Valley. The vehicle is currently in storage at the County of Riverside fleet services yard in Cabazon, CA.

## Results

From September 2016 through September 2019, the vehicle traveled over 31,100 miles.

Overall, the vehicle has performed well. A safety recall related to the lights was handled in late 2016. The vehicle and CNG technology have not experienced any significant problems except for the safety recall related to the lights and an electrical issue caused by an aftermarket 'kill switch' installed by the subcontractor for Roy's Desert Resource Center. Both issues have been corrected. CVAG's subcontractor's experience with this technology and dealership/technical support has been satisfactory.

## Benefits

While Roy's Desert Resource Center was in operation, the vehicle successfully transported homeless people to and from the emergency shelter in western Coachella Valley on a daily basis. Use of a clean vehicle with advanced technology no doubt produced fewer emissions than the older vehicle that was previously in use. It also made it easier for hundreds of homeless people to access shelter and services as they worked to get back on their feet.

## Project Costs

Purchase and registration of the CNG Van cost $137,599.50. The van was 100% funded by South Coast AQMD. Costs to insure and operate this vehicle were paid for by CVAG and its subcontractors.

## Commercialization and Applications

Keeping in regular contact with unsheltered homeless people can be a challenge, making it difficult to provide consistent services and help in securing a more permanent housing solution. In areas with reliable public transportation, bus drivers can serve as an important access point to those homeless individuals that regularly use the same familiar routes. In Coachella Valley, many areas where homeless people are located are not served by public transportation. Use of this vehicle has the potential of enhancing the region's coordinated efforts to address homelessness while also being environmentally friendly by reducing the impact on air quality.

**South Coast AQMD Contract #1633** **October 2019**

# Implement Alternative Fuel Station Expansion

## Contractor
Ontario Compressed Natural Gas (CNG)

## Cosponsors
South Coast AQMD
Mobil Source Air Pollution Reduction Review Committee (MSRC)

## Project Officer
Phil Barroca

## Background
Ontario Compressed Natural Gas (CNG) Station is a conventional fueling station located at a high vehicle-volume intersection in Ontario, CA near the Ontario Airport and the I-10 goods movement corridor. The station is positioned on a corner with access from both adjacent streets and is designed to accommodate all vehicles including heavy-duty trucks and tractor-trailer configurations. The station features a 24/7 manned Circle K convenience store, an express carwash, and a variety of conventional and alternative fuels. Conventional fuels are located on two islands and CNG and hydrogen fuel are positioned on a second set of islands. Conventional fuels include gasoline and diesel, E85, and renewable diesel. The facility also includes electric vehicle chargers including a fast charger. Prior to expansion the station had two CNG dispensers on one island. Hydrogen is produced on-site and is dispensed through with 350 bar and 700 bar nozzles. Ontario CNG sought out funding to support an expansion of the CNG station to address demand and long refueling times for consumers. Ontario CNG continues to provide solutions to overcome key barriers that have hindered the greater use of natural gas and other alternative transportation fuels, e.g. supporting infrastructure.

## Project Objective
In 2015 Ontario CNG requested funding support from the South Coast AQMD and MSRC to expand their CNG refueling capability to help address increasing demand, longer fueling times, and vehicle congestion. The project objective was to double CNG compression, double on-site storage capacity, double the number of CNG dispensers and hoses, and add one high flow nozzle on each fueling island to facilitate faster fueling of heavy-duty Class 7 and 8 vehicles. In addition, the project sought to make all necessary civil, mechanical, and electrical upgrades to support the expansion of the CNG at the site, provide incentive for fleets to use the facility by improving refueling efficiencies, reduce air pollution in this region by increasing the infrastructure of clean alternative fuel natural gas as a transportation fuel, and secure an renewable natural gas (RNG) agreement for at least 240,000 gasoline gallon equivalents (GGE)/year to help reduce greenhouse gas emissions and help reduce the Carbon Intensity of California's transportation fuel.

## Technology Description
The technology used in this funding project includes one 250 h.p. ANGI compressor package NG300 using an Ariel compressor rated at 461 scfm, two dispensers rated at 3600 psi, two high-flow Kraus-Global CT 5000 fueling nozzles (up to 5000 scfm) for heavy-duty vehicles, two standard-flow Kraus-Global CT 1000 fueling nozzles (up to 1000 scfm), three Square D electrical boxes, one electrical transformer, two air fans, four above-ground spherical storage vessels, storing 268 scf @5,500 psi, two emergency switches, two explosion valves, electrical wiring and stainless-steel tubing.

**Fig. 1 ANGI Compressor**

## Status
Ontario CNG contracted Allsup Corporation and the services of Keith Sharpe (CNG specialist, engineer) to design, permit and construct the CNG station. All equipment installations were completed and commissioning of all new equipment was executed in mid-2016.

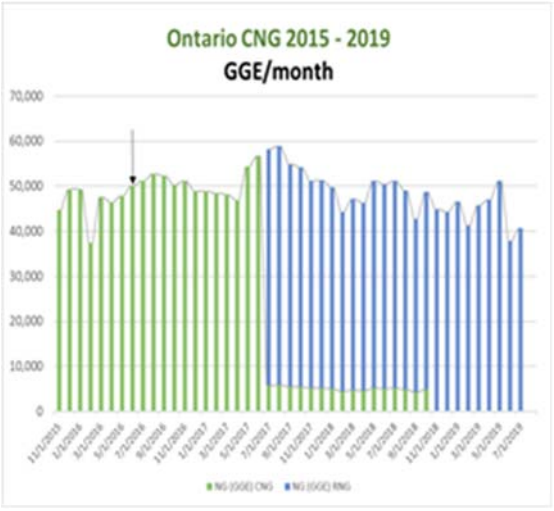
**Figure 2: CNG Station after expansion**

## Results

The Ontario CNG Station expansion project has completed its objectives of doubling its CNG fueling capacity and vehicle refueling accessibility

**Fig. 3 Class 8 Tractor/Trailer fueling for round trip run Ontario/Las Vegas**

and has reduced the waiting period for vehicle refueling. Doubling the accessibility with two fueling islands is providing Class 8 tractor-trailer rigs with the ability to pull-up and refuel without waiting. Monthly fuel throughput from November 2015 to June 2016 was 46,000 GGE. The average monthly average throughput since June 2016 is close to 51,000 GGE (see monthly fuel throughput graph below).




As the graph depicts, Ontario CNG initiated RNG fueling in mid-2017 and assumed 100% RNG fueling one year later. The station averages 50,000 GGE/month or 600,000 GGE/year thereby exceeding the RNG specifications I the contract by a factor of 1.5

## Benefits

The Ontario CNG Station project is resulting in displacing more than 50,000 GGE of petroleum-based fuel per month and through its RNG agreement is dispensing 100% RNG. Based on the most recent Greenhouse Gases, Regulated Emissions and Energy use in Transportation (GREET) model assumptions, this station is helping to reduce 600 lbs. per month of NOx emissions and 500 tons per month of $CO_2$eqv emissions. Additionally, this facility is providing convenient, reliable and fast filling of CNG to every Class vehicle from passenger class to medium-duty shuttle vans, CNG powered tow-trucks, street sweepers and school buses, and Class 8 tractor trailers that fuel at this facility for their nearly 500 mile roundtrip run between Ontario, CA and Las Vegas, NV.

**Estimated Emission Reductions/Month**

| | Fuel Displaced | | Alt. Fuel | Emission Reduced |
|---|---|---|---|---|
| | Gasoline | Diesel | RNG | |
| GGE/month | 25,000 | 25,000 | 50,000 | |
| NOx (g/GGE) | 7.225 | 7.391 | 1.854 | 13 |
| NOx (lbs/mo.) | 398 | 407 | 204 | **601** |
| $CO_2$eqv (g/GGE) | 10,785 | 10,951 | 1,637 | 20,099 |
| $CO_2$eqv (tons/mo.) | 297 | 302 | 90 | **508** |

## Project Costs

The estimated project cost was $798,535. The South Coast AQMD provided $200,000 and the MSRC provided $150,000 to this project. The final cost of the project was $751,882.

## Commercialization and Applications

The technology employed in this project includes an 4 stage Ariel compressor, spherical CNG storage vessels, cascade filling, both standard and high flow nozzles, and Kraus-Global dispensers at 3600 psi. All equipment is conventional equipment and has proven to be reliable as well as providing the consumer with easy to use dispensers. The biogas (RNG) agreement was a new experience and following initial efforts to locate and discuss terms of this agreement Ontario CNG sought the help of a brokerage firm to negotiate and define terms of the agreement.


**Fig. 4 CNG fueling of Street Sweeper, Airport Shuttle Van, Passenger Class vehicles**

**South Coast AQMD Contract # 17349** **February 2020**

# Renewable Natural Gas Research Center Project

## Contractor
University of California Riverside

## Cosponsors
Southern California Gas Company
National Center for Sustainable Transportation
University of California, Riverside

## Project Officer
Phil Barroca

## Background
Renewable Natural Gas (RNG) is pipeline quality gas that is fully interchangeable with fossil natural gas but is produced from a renewable feedstock and can be used as a 100% substitute for, or blended with, conventional natural gas. RNG is an important alternative fuel that can help the State of California meet several greenhouse gas (GHG) and renewable energy targets. As a transportation fuel, RNG can result in approximately 90% reduction in GHG emissions. Despite considerable potential, current RNG use on national and state levels are not significant.

## Project Objective
The objective of this project is to establish a Center for Renewable Natural Gas at the University of California Riverside (UCR). The project is also aimed at evaluating RNG production potential in California and conducting a survey of thermochemical conversion technologies available for RNG production. Outreach and educational activities were conducted as part of the project.

## Technology Description
The information required to construct the biomass availability assessment in California was obtained from publications by California Energy Commission, California Integrated Waste Management Board and the California Biomass Collaborative. The assessment includes estimates of the total biomass generated in California and the technical values of the amount that can be effectively utilized for fuel purposes. The gross amount of available biomass is calculated based on biomass source population and a source specific production factor. Power generation and curtailment data is from California Independent System Operator reports. Conversion technology options were evaluated using literature data.

## Status
A Final Report has been submitted and is currently under review. All other aspects of the project have been completed. The results of this research effort have been presented at the 2018 RNG conference held in Monarch Bay, CA and the 2018 RNG Works conference held in Denver, CO. The research team has also presented the results to interested stakeholders including state agency staff. Additional information about these presentations are available upon request.

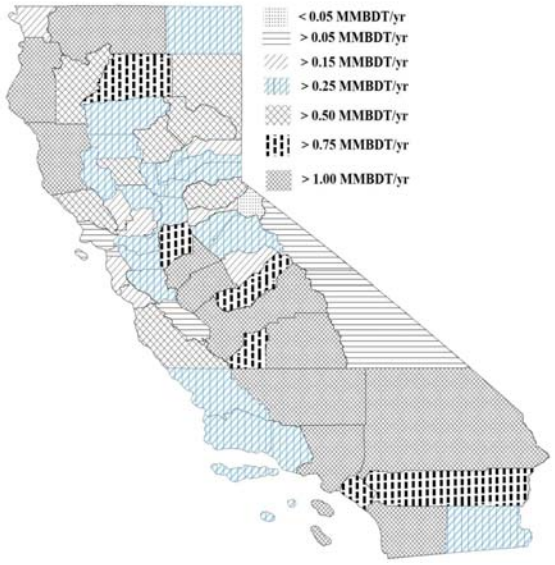
## Results
RNG production potential in California through thermochemical conversion was evaluated by assessing technical biomass availability in the state. Biomass feedstocks are defined broadly and include most carbonaceous matter including waste. The types of waste biomass available in the state are classified into three categories: municipal solid waste (MSW), agricultural residue and forest residue.

MSW is the largest biomass contributor in the state with approximately 18.0 million bone-dry tons (MMBDT)/year of technical production. The technical availability estimates of agricultural residues (including animal manure, food processing and fiber-based feedstocks) is about 8.6 MMBDT/year. The technical forest residue biomass availability in California is about 14.3 MMBDT/year. A total of 32.1 MMBDT/year of biomass is estimated to be technically available in the state. The energy content of this biomass is equivalent to approximately 602 million British thermal units per year.

A survey of current renewable electricity generation and curtailment trends in California was conducted. A total of 615 solar power plants and 128 wind power plants are currently under operation in in the state. Real-time data from November 2016 to October 2017 show significant curtailment throughout the year ranging from 6.2 GWh to 85.2 GWh. During the entire twelve-month study period, about 440 GWh of power was curtailed in California. Power to gas and

other forms of long-term storage integrated into the electric grid can mitigate these losses and also allow smooth integration of additional renewables into the grid.

Oxygen/air blown gasification, hydrogasification and pyrolysis are the three major technology options available for thermochemical biomass conversion to a gaseous fuel, including RNG. A literature survey of available thermochemical conversion technologies was conducted. Although no commercial thermochemical biomass to RNG conversion facilities are currently in operation, several gasification and pyrolysis technologies are undergoing pilot scale demonstration and development. Design basis for two thermochemical and power-to-gas conversion projects were developed as part of this project. Significant research, development, and deployment efforts are necessary to achieve successful commercialization of thermochemical RNG production.



California Biomass Resource Distribution Map

Outreach and education activities including a ribbon cutting ceremony for the Center for Renewable Natural Gas and an RNG themed symposium were also conducted as part of the project.

## Benefits

As part of this grant, UCR has established a research center dedicated to the development of technologies that will enable RNG production and use in substantial quantities in California and elsewhere. The new center, referred to as the Center for Renewable Natural Gas, leverages on-going research and collaborations at the Bourns College of Engineering – Center for Environmental Research & Technology (CE-CERT) at UCR to maximize the impact.

The production potential estimates show that significant resources are available in the state that can be converted into RNG through thermochemical processes such as gasification and pyrolysis.

Design basis for a demonstration scale thermochemical RNG production facility and a commercial scale power to gas project that will produce hydrogen from wind power were developed as part of the project.

The UCR CE-CERT hosted a ribbon cutting ceremony for the Center for Renewable Natural Gas and a Renewable Natural Gas Symposium was held on May 17, 2017. The symposium included talks and in-depth discussions of RNG adoption from lab to market and was attended by more than 200 participants. Guest speakers included representatives from the CEC, the Southern California Gas Company, CARB, Fuel Cell & Hydrogen Technologies, and the National Renewable Energy Laboratory. Panel discussion topics included Thermochemical RNG Production, Commercial Scale Power to Gas, RNG Policy in California, and Challenges to Expediting Commercial RNG Production.

## Project Costs

The project was completed within budget with a total funding of $261,110. Cost-sharing was as follows: South Coast AQMD ($100,000), Southern California Gas Company ($100,000), National Center for Sustainable Transportation (NCST) ($25,000), and $36,000 of in-kind contribution in the form of facility fee waivers from UCR.

## Commercialization and Applications

The survey of thermochemical conversion technologies included design basis development for two projects. The Center for Renewable Natural Gas is pursuing funding opportunities for these projects in partnership with the technology developers and will assist in relevant demonstration and commercialization activities.

**South Coast AQMD Contract #15607** **January 2019**

# Innovative Transportation System Solutions for NOx Reductions in Heavy-Duty Fleets


## Contractor
University of California, Riverside
Bourns College of Engineering–Center for Environmental Research and Technology

## Cosponsors
University of California Transportation Center (UCTC)

## Project Officer
Seungbum Ha


## Background
Heavy-duty trucks are a critical component of U.S. goods movement; however, these trucks consume a large amount of fuel and emit significant emissions, namely the greenhouse gas CO2, and the air pollutants, particulate matter (PM) and NOx. The objective of this project is to develop an intelligent transportation system to reduce the impact of heavy-duty truck NOx emissions on air quality and public health, and to quantify the potential NOx reductions in the South Coast Air Basin emission inventory.

In this project, the College of Engineering-Center for Environmental Research and Technology (CE-CERT) developed a routing methodology and a set of algorithms specifically designed to minimize NOx emissions for four model year groups of heavy-duty trucks. This work builds on CE-CERT's previous research in the area of eco-routing algorithms for light-duty and heavy-duty vehicles. Selected validation was performed on two heavy-duty trucks which were tested in the field. The effectiveness of the NOx-minimizing routing algorithms was evaluated and their potential for NOx emission savings was estimated. The in-field testing shows NOx savings of at least a 17% for the low NOx routes. Although this result is difficult to extrapolate to a larger scope, it implies the potential for significant NOx emission reductions with the use of intelligent routing.

## Project Objective
In previous research at CE-CERT, various eco-routing algorithms for passenger vehicles and heavy-trucks were developed. This work focused on expanding these efforts to include routing by minimized NOx emissions for heavy-duty trucks.

The objectives of this project are as follows:
1. Develop a routing system to provide eco-friendlier routes for heavy-duty trucks to help reduce their impact on air quality and public health, specifically with regard to the pollutant NOx
2. Perform field testing to validate the routing system
3. Discuss the potential NOx reduction benefits of implementing intelligent routing system for HDD.

The research in this project focuses on the following truck categories: Pre-2004, 2004-2006, 2007-2009 and 2010+. In-field testing and validation were performed with two vehicles in the 2010+ vehicle category.

## Technology Description
Eco-routing for this project determines the NOx minimized route on a roadway network between an origin and destination point for a given vehicle and real-time traffic conditions. Routing is based on average link velocity, current vehicle selective catalytic reductions (SCR) temperature (if available) and static vehicle and network parameters such as roadway grade, link length and vehicle mass.

Routing uses the popular Dijkstra's single-source shortest path algorithm. Distance based emission rates are developed using operating mode-based emission rates from the Motor Vehicle Emission Simulator (MOVES) database. To generate the distance based emission rates, MOVES drive cycles representative of heavy-duty trucks are modeled using MOVES emission rates for various vehicle weights and road grades. The average drive cycle velocity, vehicle weight and grade are associated with a gram per mile emission value to create an emission rate lookup table.

Vehicle categories 1-3 are none Selective Catalytic Reduction (SCR) equipped trucks and NOx emissions for these vehicles at any time are primarily impacted by vehicle activity at that time (i.e. not path dependent). Routing for these vehicles uses the developed distance based emission rates and link length to calculate link emissions as required by the routing algorithm.

Vehicle category 4 is 2010+ SCR equipped trucks. For these vehicles, NOx emissions are heavily dependent on SCR operating temperature, which in turn is heavily dependent on the SCR operating temperature from the preceding link (i.e. path dependent). For these vehicles, a two-step routing process is used in order to decrease the computational complexity and demand on the routing algorithm of tracking multiple temperature histories for each links.

In the two-step approach, candidate routes are determined in the first step based on the shortest time or distance. In the second step, NOx emissions for each candidate route is modeled in it's entirety using emission rates from a specially developed emission rate lookup table and temperature corrections based on a link-based SCR temperature and efficiency model.

The SCR temperature model uses a Multivariable Linear Regression (MLR) modeling approach to associate the average SCR temperature on a link with the average SCR temperature on the previous link, the link velocity, link length and link grade.

The temperature model estimates SCR temperature throughout a route. SCR temperature is used to adjust emission factors based on SCR temperature related NOx conversion efficiency. Temperature adjusted distance based emission rates and link length are used to calculate NOx emissions on each link. Link NOx emissions are integrated over each candidate route to calculate total NOx emissions for each candidate route to determine the NOx minimized route.

## Status

This project was completed on January 31, 2019. The final report is on file with South Coast AQMD and provides details of the routing system.

## Results

Data collection was performed for 4 vehicle trips, each trip consisting of two competing routes. Measured emission data from the routes were calculated and compared with results from the NOx routing method developed in this project. Results show the error between the estimated NOx from the routing model and NOx emissions from the electronic control unit (ECU). More importantly, results show the comparison of NOx emissions from both routes for the modeled and measured data. The results show the following:

- The routing model was able to correctly predict the low NOx route in each case, even though the lowest NOx emission route was not necessarily the shortest in time or distance.
- Measured NOx between competing routes shows NOx differences in the range from 17% to 91%.
- The lowest NOx routes were also the shortest time routes for half of the trips.
- The lowest NOx routes were the longest distance routes and had the highest fuel consumption in all cases. Reduced NOx routes showed higher fuel consumption in the range of 7% to 32%.
- The lowest NOx routes had the highest average trip speed in all cases. This is not necessarily surprising since increased SCR performance depends on higher exhaust temperatures which usually occurs when the engine load is high, consuming more fuel.
- Modeled NOx prediction error was in the range of 16% to 79%. This level of error is expected since there are many sources of potential error including the accuracy of collected NOx data and the link-level resolution of the modeling process.

## Benefits

Validation results of the routing model show the potential for significant NOx emission reductions due to proper route choice. In the cases tested, results show measured savings of at least 17% between competitive routes. These results are difficult to extrapolate to a larger scope, however they do imply the potential for significant NOx emission reductions with the use of intelligent routing. Reductions in NOx emissions were shown to come at the expense of higher fuel consumption.

## Project Costs

The total project cost is estimated at $139,980 and South Coast AQMD's share was $79,980 from the Clean Fuels Fund. The research under this contract is an expansion of research performed by UC, Riverside under the UCTC project "Eco-Friendly Navigation System Research for Heavy-Duty Trucks".

## Commercialization and Applications

This research may have important implications in the area of heavy-duty truck routing. The research demonstrates the ability of the truck routing system to evaluate the cost of a route in terms of NOx emissions with sufficient accuracy to predict the lowest cost NOx route. This technology could be added to any routing system with real-time traffic information.

**South Coast AQMD Contract #15636** **December 2019**

# Evaluate PEV Utilization through Advanced Charging Strategies in a Smart Grid System


## Contractor

University of California, Riverside (UCR)

## Cosponsors

Winston Batteries Ltd.
SolarMax Technology, Inc.

## Project Officer

Alfonso Baez


## Background

The South Coast AQMD Board and staff previously prioritized in-basin renewable distributed electricity generation and storage to support electric vehicle technology applications. UC Riverside has successfully deployed plug-in electric vehicle (PEV) integrated microgrid operations consisting of 500kW of photovoltaic (PV) generation coupled with 2 MWh of energy storage. This project further advances the utilization of microgrid integrated charging of PEVs by optimizing charging activity and vehicle-to-grid (V2G) operations.

## Project Objective

The main objective of this project is to optimize PEV charging within a microgrid testbed that demonstrates the coordinated integration and management of energy assets including: renewable generation, energy storage, and controllable loads to effectively manage PEV energy needs. The microgrid system was further expanded to optimize V2G activities relative to driver needs and microgrid operations.

## Technology Description

The deployed microgrid testbed consists of PV generation coupled with battery energy storage and facility load management to support electric vehicle (EV) charging of passenger vehicles and an electric transit vehicle. The system continuously monitors energy production, storage, demand and vehicle charging requirements to optimize daily energy needs. Peak electrical load demand from the utility is minimized while facilitating the charging of electric vehicles. V2G functionality allows for expanded energy storage algorithms and system optimization. Microgrid management decisions have been implemented and utilized to maximize grid stability, reliability, vehicle usage, and efficiency.

## Status

This project was initiated in January 2016 and completed on December 31, 2019. The final report is on file with South Coast AQMD and provides full details of the V2G system integration, architecture, design, installation, operation, benefits and results. The microgrid continues to operate and has provided V2G functionality transferable to microgrid PEV coupled deployments throughout California. The deployment and operational team continues to develop and deploy PEV integrated microgrids based on the achievements demonstrated with this South Coast AQMD-sponsored V2G testbed deployment.


**PEV connected to energy storage with V2G capability.**

## Results

PEV integration and optimization within the microgrid allows for more efficient energy management. The increased energy efficiency and reduced losses allows for emissions reduction of both greenhouse gas (GHG) and criteria pollutant emissions compared to the baseline scenarios.

The system performance evaluation includes emissions, energy efficiency, operation and maintenance requirements, overall environmental impacts, and performance tradeoffs. The 10 year PEV project lifetime reduction utilizing the efficiency gains achieved through optimized PEV charging will reduce 36,790 kWh of electrical generation which is approximately 19.5 tons of $CO_2$ equivalent greenhouse gases.

| | Grid Power (CAMX Mix) | Solar PV Generation |
|---|---|---|
| GHGs ($gCO_2e$/kWh) | 539 | 9 |
| NOx (g/kWh) | 0.68 | 5.8E-03 |
| SOx (g/kWh) | 0.38 | 9.8E-04 |

**Project life GHG and criteria pollutant emissions on a kWh generation basis for grid power and solar generation calculated using microgrid PEV optimization.**

## Benefits

Daily energy management system (EMS) control algorithms for PEV charging provide energy savings, peak demand shaving, and cost reductions during all three different time-of-use (TOU) rate periods. The system configuration is optimized for on-peak demand reduction and savings. Load shifting operations are managed with off-peak battery charging and discharging during on-peak and mid-peak rate periods. The shift of energy consumption results in substantial savings.


**Energy from UC Riverside's V2G trolley bus being utilized to mitigate peak demand.**

The most significant energy savings are achieved utilizing real-time control algorithms that track real time solar PV generation, battery energy capacity, energy demand, and PEV activity. The algorithms developed and deployed minimize peak loads for specific buildings while simultaneously reducing peak energy demand charges. The demand charge savings is about one-third (1/3) of total savings. The figure shows peak demand reduction achieved by charging the electric trolley during periods of excess solar PV production and discharging during evening on-peak demand when solar production diminishes. This load shifting activity demonstrates mutual energy benefits to both the utility and the rate payer.

## Project Costs

The cumulative value of the project to date is $8,813,100 when considering the original deployment and system additions. Continued energy savings further increase the value and expanded benefits of the project. The South Coast AQMD provided funding at a level of $2,170,000. The remaining $6,643,100 was provided as cost-share by the University of California, Riverside ($839,388), Winston Batteries Ltd. ($5,000,000), and SolarMax Technology Inc. ($803,712).

## Commercialization and Applications

The developed technologies of demand charge management, zero net energy building management, and electric vehicle charging mitigation are at an early stage of development and demonstration. These technologies have a potential for maximizing the benefits from distributed assets and lowering electricity costs within commercial and industrial facilities.

This project has successfully completed the following activities leading to further commercialization potential:

- Deployment and management of solar PV generation to offset PEV charging
- Integration of battery energy storage to maximize facility and PEV use supported by renewable generation
- Advanced EMS algorithms to manage battery activity, controllable loads, and facility needs
- Regional monitoring of EV charging and power requirements
- Grid management algorithm development to utilize the stored electricity for PEV charging needs that has minimal electric grid impact
- Integration and optimization of V2G technology
- Quantification of microgrid benefits
- Final reporting to SCAQMD.

**South Coast AQMD Contract #17331** **October 2019**

# Conduct In-Use PM Emissions Study for Gasoline Direct Injection Vehicles


## Contractor

University of California Riverside, Center for Environmental Research and Technology

## Cosponsors

MECA

## Project Officer

Joseph Lopat


## Background

Currently, there is an increased concern in both the United States (US) and European Union (EU) about the degradation of the actual atmospheric pollution levels of nitrogen oxides (NOx) and particulate matter (PM) in spite of the stricter vehicle emission limits in recent years. Differences between conditions for chassis or engine test cycles defined by vehicle emission regulations and real driving can contribute to the differences between expected and actual pollution levels. Recent air quality studies show significant exceedances for NOx and PM emissions, mainly in urban areas with high populations where emissions are mainly contributed by transport sources. Portable emission measurement systems (PEMS) were introduced and have been used for the purpose of investigating and regulating real driving emissions (RDE) of vehicles.

## Project Objective

This program evaluated the gaseous and particulate emissions from 3 current model year gasoline direct injection (GDI) vehicles using PEMS. Testing on two of the GDI vehicles was conducted with and without catalyzed gasoline particle filters (GPFs). All vehicles were tested on-road on four routes that were designed to be broadly different in order to differentiate vehicle operating effects on the exhaust emissions. The test routes were chosen to reflect a relatively rich diversity of topological characteristics, altitudes, driving patterns, and ambient conditions representative of typical vehicle operation in Southern California. The goal of this study was to investigate the real-world emissions from GDI vehicles, including NOx and ultrafine particles, under a variety of driving conditions mimicking urban, rural, and highway driving patterns, and included changes in altitude, road grade, and environmental conditions.

## Technology Description

For this program, 3 current model year GDI vehicles were used. For two vehicles, a catalyzed GPF was installed in place of the underfloor three-way catalytic converter (TWC). The GPFs were sized based on the engine displacement of each vehicle and they were catalyzed with precious metal loadings typical of underfloor catalysts matching the certification levels of the two vehicles. The third vehicle was used to develop routes for baseline testing.

## Status

This project was successfully completed in December 2018. Comprehensive data analysis for real-world emissions was completed in August 2019. The College of Engineering-Center for Environmental Research and Technology (CE-CERT) produced a journal paper describing the results of this project that will also serve as the final report. To date, one journal paper has been submitted and several presentations in different national and international conferences have been conducted.

**Figure 1: Portable emissions equipment attached to late model automobile.**

## Results

Results showed elevated emissions during on-road testing that will likely affect air quality and health in populated areas in the South Coast Air Basin. However, the use of catalyzed GPFs in older and

current technology GDI vehicles can be proved an effective tool to mitigate gaseous and particulate emissions. Results revealed significant reductions in soot mass or black carbon emissions and particle number emissions with the catalyzed GPFs over all test routes.

Under the present test conditions, mountainous driving showed elevated PM emissions compared to driving without elevation change. It is important to note that the highest PM emissions were seen for the urban routes (i.e., downtown LA and downtown San Diego) where public exposure for these pollutants is highest. All test routes showed greater soot mass and particle number emissions for the low and intermediate speed bins and high acceleration events, typical of start and stop driving patterns at traffic lights and congested roads.

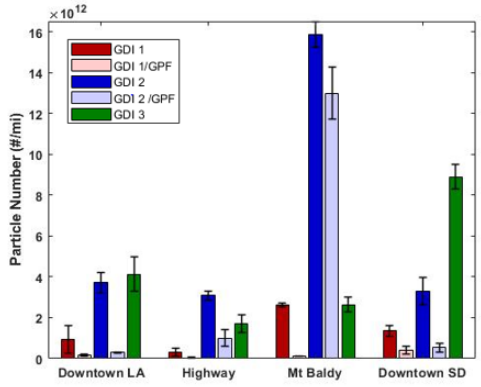



**Figure 2: Particulate Number emissions measured on-road in 4 routes.**

Catalyzed GPFs were found to be effective in reducing NOx emissions due to the additional catalytic volume compared to the original TWC configuration, suggesting additional NOx reductions in real-driving conditions. It should be stressed however, that NOx emissions for some of the vehicles on some of the test routes significantly exceeded the NOx emissions certification standard. These are important findings considering that adverse health effects of NO2 and NOx emissions will affect urban air pollution by participating in the ground level ozone formation. Higher on-road NOx emissions from the passenger car sector will challenge current and future efforts in California to meet the requirements for ambient ozone driven by the National Ambient Air Quality Standard. In addition to NOx emissions, carbon monoxide (CO) emissions were found to exceed the certification standards for some vehicles and test routes. CO emissions demonstrated increases over the more dynamic urban routes and did not show reductions with the catalyzed GPFs over real-world conditions.

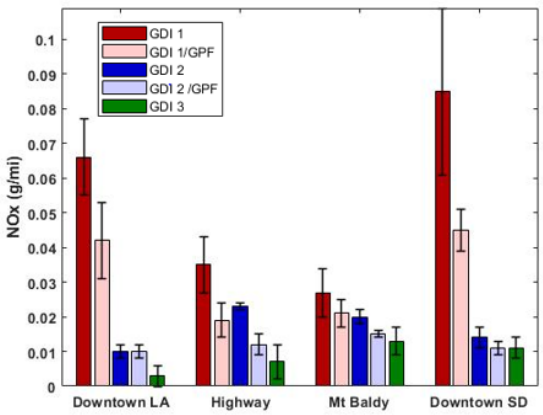



**Figure 3: NoX measured on-road in 4 routes.**

## Benefits

It is important to understand the real-world emissions from current GDI vehicles. Our findings suggest that GDI vehicles are important sources of tailpipe on-road PM and NOx emissions and will also be important contributors to secondary organic aerosol (SOA) formation due to precursor emissions responsible for SOA. The projected increased penetration of GDI vehicles in the US market, suggests that future health studies aimed at characterizing the toxicity of GDI emissions, as well as studies for the better understanding of SOA production from these engines are needed to understand the health and air quality risks associated with non-GPF-equipped GDI emissions. The fact that GPF adoption from US vehicle manufacturers is not as dynamic as in the European Union, due to the more stringent European particle number standard especially over RDE testing, should raise concerns about the lack of societal and air quality benefits from the GDI fleet.

## Project Costs

| | South Coast AQMD | MECA | Total |
|---|---|---|---|
| Testing & Reporting | $222,000 | $51,500 | $273,500 |

## Commercialization and Applications

It is expected that GDI vehicles will be a major source of air pollution in urban centers. Real-world emissions and the mechanisms of their formation under different driving patterns need to be further investigated. The use of GPFs will be proved very effective in reducing black carbon and ultrafine particle emission.

**South CoastAQMD Contract # 17367** **November 2019**

# Develop & Evaluate Aftertreatment Systems for Large Displacement Diesel Engines


## Contractor

Southwest Research Institute (SwRI)

## Cosponsors

South Coast AQMD
U.S. EPA
California Air Resources Board (CARB)
Manufacturers of Emissions Controls (MECA)

## Project Officer

Joseph Lopat


## Background

The original ARB Low $NO_X$ Demonstration program involved an examination of the feasibility of technologies to achieve a target tailpipe $NO_X$ level of 0.02 g/hp-hr on both a diesel and natural gas engine platform. A key part of the technical demonstration involved aging of the final system engine in an accelerated fashion to simulate full useful life degradation, so that the system performance could be demonstrated at the end of useful life. However, during that aging process an unexpected failure occurred which disturbed the experiment, resulting in the exposure of the aftertreatment system to unrepresentative conditions. The failure involved the canning of the Passive $NO_X$ Adsorber (PNA), which in turn resulted in failure materials being ingested into the downstream SCR-on-Filter (SCRF). The failure is illustrated in Figure 1. Due to time and budget constraints, the experiment could not be restarted. Although the parts were repaired, and the experiment was completed, the failure left two open issues:

- How much of the degradation observed in the original Stage 1 experiment was "normal," versus how much was "abnormal" (resulting from the unrepresentative failure conditions).
- The SCRF was left in a fragile state following the failure, with several areas of channel micro-cracking that could later expand to a full failure with continued use. This was an issue because the parts were needed to support Low Load calibration and demonstration efforts in the CARB Stage 2 program.

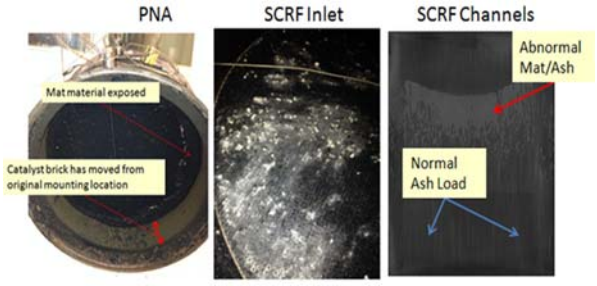



**Figure 1. Illustration of Stage 1 Failure on PNA and Downstream SCRF**

## Project Objective

SwRI will develop, age and test a second set of catalysts to represent real-world low load and low temperature test cycles. The parts will be aged for 1,000 hours and emissions testing will be performed at set intervals along the Federal Test Procedure (FTP) transient cycle. Once complete, the new hardware will be tested with the engine under the developed cycles from Stage 1. The objective of this effort is to overcome the aging issues encountered in Stage 1, as well as to provide a robust aftertreatment system for the next phase of work, which will include development of a larger displacement diesel engine suitable for long-haul operations, including an aftertreatment system optimized to achieve the 0.02 g/bhp-hr NOx emissions level.

## Technology Description

The diesel demonstration platform was a 2014 Volvo MD13TC EU6 engine. The final configuration of the low $NO_X$ aftertreatment system is shown in Figure 2.

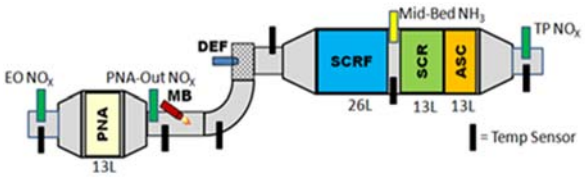



**Figure 2. Final Stage 1 Low $NO_X$ Aftertreatment System Configuration**

## Status

The project was completed August 4, 2019. The final report is on file at South Coast AQMD and on

the CARB website. The objectives were eventually met. A catastrophic engine failure occurred and was determined not to have affected the results. The engine critical components related to emissions were not damaged and were re-used in a new engine assembly.

## Results

The Stage 1b Test plan involved repeating the 1000-hour accelerated aging experiment that was performed under Stage 1, using a fresh set of parts identical to the original parts. To gain better insight into system degradation over time, the parts were tested at two intermediate points during aging, in addition to before and after the completion of the full aging duration. Tests were conducted at the 0-hour point (following de-greening), and at 33%, 67%, and 100% of the full useful life (FUL) aging duration of 1000 hours. The aging was conducted using the SwRI-developed DAAAC (Diesel Accelerated Aftertreatment Aging Cycles) methodology, which accounts for both thermal and chemical aging components. For this experiment, the aging achieved a full 10X acceleration of thermal aging, and a 4.5X acceleration of chemical aging. However, at the end of aging, the SCRF contained a near maximum life duration of ash loading, prior to ash cleaning. To assess the impact of ash cleaning on the SCRF, an additional ash cleaning experiment and test were added to the test plan, supported by the Manufacturers of Emissioin Controls Association (MECA). Final results of the Stage 1b program are summarized in Figure 3. The results indicate the following trends:

- Cold-Start FTP performance in Stage 1b was similar to that observed during Stage 1. Cold-start performance loss is driven primarily by loss of PNA performance. This indicates that the canning failure did not disturb the aging of the PNA itself.
- Hot-Start Standard Test Procedures (STP) performance in Stage 1b was considerably better than what was observed in Stage 1. The system maintained 99.6% $NO_X$ conversion in Stage 1b, as compared to only 99.3% in Stage 1. This was primarily driven by the behavior of the SCRF, and it indicates that the SCRF was significantly disturbed by the upstream canning failure in Stage 1.
- Composite FTP $NO_X$ levels were 0.023 g/hp-hr after ash cleaning in Stage 1b, as opposed to 0.034 g/hp-hr in Stage 1, a considerable performance improvement.
- RMC-SET $NO_X$ levels were 0.032 g/hp-hr in Stage 1b as opposed to 0.038 g/hp-hr in Stage 1, again due primarily to the better performance of the SCRF that was not subjected to the upstream canning failure.

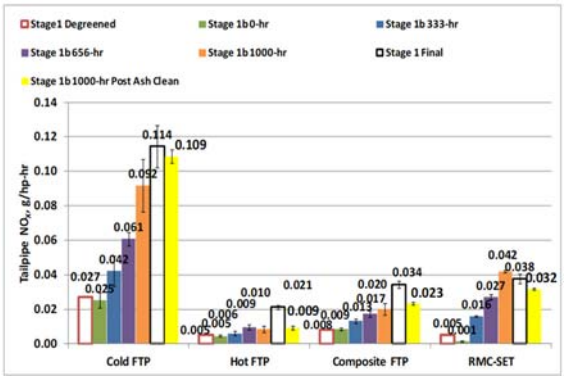



**Figure 3. Final Results for Stage 1b Program (showing comparison to Stage 1 results)**

## Benefits

The known useful life of an aftertreatment system is valuable in predicting current and future emissions. Modeling emissions inventories can be more accurate using data provided in this project. Data such as the percent NOx conversion at the end of useful life. This project success was also important as it was the first stage in the development of a heavy-duty near zero NOx diesel engine.

## Project Costs

The project was the first stage addition with a total cost of $480,000. $80,000 was contributed in-kind by MECA. The remaining funds were contributed by the US EPA Clean Air Technolgy Initiative grant with $290,000 and the South Coast AQMD with $110,000.

## Commercialization and Applications

This program is an important data point regarding the capability of heavy-duty diesel engines to reach Low $NO_X$ levels in a durable manner. The system proved to be capable of high $NO_X$ conversion at both high loads and light loads. As such the data is applicable to heavy-duty engines in a variety of applications, including both line haul tractors and vocational applications.

The aftertreatment system aged in this program was also used to support the CARB Stage 2 program, which extended the performance of the system to Low Load applications such as urban and drayage duty cycles.

Several technology elements of the engine and aftertreatment system could potentially be incorporated in future on-highway engines to meet Low $NO_X$ standards.

# Appendix D

# Technology Status

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# Technology Status

For each of the core technologies discussed earlier in this report, staff considers numerous factors that influence the proposed allocation of funds, ranging from overall Environment & Health Benefits, Technology Maturity and Compatibility, and Cost, summarized in this technology status evaluation system.

Within the broad factors included above, staff has included sub-factors for each specific type of project that may be considered, as summarized below:

### Environment and Health

Criteria Pollutant Emission Reduction potential continues to receive the highest priority for projects that facilitate the NOx reduction goals outlined in the 2016 AQMP. Technologies that provide co-benefits of Greenhouse Gas and Petroleum Reduction are also weighted favorably, considering the Clean Fuels Program is able to leverage funds available through several state and federal programs, as well as overall health benefits in reducing exposure to Ozone and PM2.5, especially along disadvantaged communities.

### Technology Maturity & Compatibility

Numerous approaches have been used to evaluate technology maturity and risk that include an evaluation of potential uncertainty in real world operations. This approach can include numerous weighting factors based on assessed importance of a particular technology. Some key metrics that can be considered include Infrastructure Constructability that would evaluate the potential of fuel or energy for the technology and readiness of associated infrastructure, Technology Readiness that includes not only the research and development of the technology, but potential larger scale deployments that consider near-term implementation duty and operational compatibility for the 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 the technology research, development, demonstration and deployment projects. Therefore, in an effort to accelerate the demonstration and deployment, especially some pre-commercialization technologies, incentive programs such as those available from local, state and federal programs are key, but may be underfunded for larger scale deployments.

Staff has developed an approach to evaluating the 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 state 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 it is noted that technology developers, suppliers and other experts may differ in their approach to ranking these projects. For example, staff ranks Electric/Hybrid Technologies and Infrastructure as Excellent or Good for Criteria Pollutant and GHG/Petroleum Reduction, but Poor to Good for Technology Maturity & Compatibility, and Satisfactory to Unacceptable 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 & Infrastructure** | | | | | | | | | |
| Plug-In Hybrid Heavy-Duty Trucks with Zero-Emission Range | ◓ | ○ | ◓ | ● | ○ | ◓ | ◓ | ◒ | ● |
| Heavy-Duty Zero-Emission Trucks | ● | ◓ | ● | ◓ | ○ | ◒ | ○ | ● | ● |
| Medium-Duty Trucks | ◓ | ◓ | ● | ◓ | ○ | ○ | ◒ | ◒ | ● |
| Medium- and Heavy-Duty Buses | ● | ◓ | ● | ◓ | ○ | ◒ | ○ | ◒ | ● |
| Light-Duty Vehicles | ◓ | ◓ | ● | ◓ | ◓ | ◓ | ◓ | ○ | ◒ |
| Infrastructure | - | - | - | ◓ | ◓ | ◓ | ◓ | ◒ | ● |
| **Hydrogen & Fuel Cell Technologies & Infrastructure** | | | | | | | | | |
| Heavy-Duty Trucks | ● | ◓ | ◓ | ○ | ◒ | ◒ | ◒ | ● | ● |
| Heavy-Duty Buses | ● | ◓ | ◓ | ○ | ◒ | ◒ | ◒ | ● | ● |
| Off-road – Locomotive/Marine | ● | ◓ | ◓ | ○ | ◒ | ◒ | ◒ | ● | ● |
| Light-Duty Vehicles | ● | ◓ | ◓ | ○ | ◓ | ○ | ○ | ◒ | ◒ |
| Infrastructure – Production, Dispensing, Certification | - | - | - | ○ | ○ | ◒ | ◒ | ● | ◒ |
| **Engine Systems** | | | | | | | | | |
| Ultra-Low emissions Heavy-Duty Engines | ◓ | ◓ | ◓ | ● | ○ | ○ | ● | ◓ | ○ |
| Alternative Fuel Medium- and Heavy-Duty Vehicles | ◓ | ◓ | ◓ | ● | ◓ | ◓ | ● | ◓ | ○ |
| Off-Road Applications | ◓ | ◓ | ◓ | ● | ◓ | ◓ | ● | ◓ | ○ |
| **Fueling Infrastructure & Deployment** | | | | | | | | | |
| Production of Renewable Natural Gas – Biowaste/Feedstock | ◓ | ● | ◓ | ● | ◓ | ◓ | ◓ | ◒ | ◒ |
| Synthesis Gas to Renewable Natural Gas | ◓ | ● | ◓ | ● | ◓ | ◓ | ◓ | ○ | ○ |
| Expansion of Infrastructure/Stations/Equipment/RNG Transition | ◓ | ◓ | ◓ | ● | ◓ | ◓ | ◓ | ◓ | ○ |
| **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 | ◓ | ○ | ◓ | ○ | ○ | ◓ | ◓ | ◓ | ○ |
| Lower-Emitting Lubricant Technologies | ○ | ○ | ● | - | ◓ | ◓ | ◓ | ● | ○ |

● Excellent ◓ Good ○ Satisfactory ◒ Poor ● Unacceptable

# Appendix E

# List of Acronyms

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# LIST OF ACRONYMS

AB—Assembly Bill
AC—absorption chiller
ADA—American with Disabilities Act
AER—all-electric range
AFRC—air/fuel ratio control
AFVs—Alternative Fuel Vehicles
APCD—Air Pollution Control District
AQMD—Air Quality Management District
AQMP—Air Quality Management Plan
ARB—Air Resources Board
ARRA—American Recovery & Reinvestment Act
AWMA—Air & Waste Management Association
BACT—Best Available Control Technology
BET—battery electric truck
BEV—battery electric vehicle
BSNOx—brake specific NOx
BMS—battery management system
CAAP—Clean Air Action Plan
CAFR—Comprehensive Annual Financial Report
CaFCP—California Fuel Cell Partnership
CARB—California Air Resources Board
CATI—Clean Air Technology Initiative
CBD—Central Business District (cycle) - a Dyno test cycle for buses
CCF—California Clean Fuels
CCHP—combined cooling, heat and power
CCV—closed crankcase ventilation
CDA—cylinder deactivation
CDFA/DMS—California Department of Food &Agriculture/Division of Measurement Standards
CEC—California Energy Commission
CE-CERT—College of Engineering – Center for Environmental Research and Technology
CEMS—continuous emission monitoring system
CEQA—The California Environmental Quality Act
CFCI—Clean Fuel Connection, Inc.
CFD—computational fluid dynamic
CHBC—California Hydrogen Business Council
CHE—cargo handling equipment
CNG—compressed natural gas
CNGVP—California Natural Gas Vehicle Partnership
$CO_2$—carbon dioxide
CO—carbon monoxide
ComZEV—Commercial Zero-Emission Vehicle
CPA—Certified Public Accountant
CPUC—California Public Utilities Commission
CRDS—cavity ring-down spectroscopy
CRT—continuously regenerating technology
CVAG—Coachella Valley Association of Governments
CWI—Cummins Westport, Inc.
CY—calendar year
DC—direct connection
DCFC—direct connection fast charger
DCM—dichloromethane
DEG—diesel equivalent gallons
DGE—diesel gallon equivalents
DF—deterioration factor
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
DPT3—Local Drayage Port Truck (cycle) - where 3=local (whereas 2=near-dock, etc.)
DRC—Desert Resource Center
DRI—Desert Research Institute
ECM—emission control monitoring
EDD—electric drayage demonstration
EDTA—Electric Drive Transportation Association
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
EVSE—electric vehicle supply equipment
FCEB – fuel cell electric bus
FCV—fuel cell vehicle
FTA—Federal Transit Administration
FTP—federal test procedures
g/bhp-hr—grams per brake horsepower per 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
GHG—Greenhouse Gas
GNA—Gladstein, Neandross & Associates, LLC
GREET- Greenhouse Gasses, Regulated Emissions and Energy Use in Transportation
GTL—gas to liquid

## LIST OF ACRONYMS (cont'd)

GVWR—gross vehicle weight rating
H&SC—California Health and Safety Code
HCCI—Homogeneous Charge Combustion Ignition
HCNG—hydrogen-compressed natural gas (blend)
HDDT—highway dynamometer driving schedule
HD-FTP—Heavy-Duty Federal Test Procedure
HD-OBD—heavy-duty on-board diagnostics
HPLC—high-performance liquid chromatography
HT—high throughput
HTFCs—high-temperature fuel cells
H2NIP—Hydrogen Network Investment Plan
HTPH—high throughput pretreatment and enzymatic hydrolysis
HyPPO—Hydrogen Progress, Priorities and Opportunities report
Hz—Hertz
ICE—internal combustion engine
ICEV—internal combustion engine vehicle
ICU—inverter-charger unit
ICTC—Interstate Clean Transportation Corridor
IVOC—intermediate volatility organic compound
kg—kilogram
LACMTA—Los Angeles County Metropolitan Transit Authority
LADOT—City of Los Angeles Dept. of Transportation
LADWP—Los Angeles Department of Water and Power
LCFS—Low Carbon Fuel Standard
Li—lithium ion
LIMS—Laboratory Information Management System
LLNL—Lawrence Livermore National Laboratory
LNG—liquefied natural gas
LPG—liquefied petroleum gas or propane
LSM—linear synchronous motor
LSV—low-speed vehicle
LUV—local-use vehicle
LVP—low vapor pressure
MATES—Multiple Air Toxics Exposure Study
MECA—Manufacturers of Emission Controls Association
MOA—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
MY—model year
MTA—Metropolitan Transportation Authority (Los Angeles County "Metro")
NAAQS—National Ambient Air Quality Standards
NAFA—National Association of Fleet Administrators
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
NH3—ammonia
NHTSA—Natural Highway Traffic Safety Administration
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
NSPS—New Source Performance Standard
NSR—New Source Review
NZ—near zero
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
PAH—polyaromatic hydrocarbons
PbA—lead acid
PCM—powertrain control module
PEMFC—proton exchange membrane fuel cell
PEMS—portable emissions measurement system
PEV—plug-in electric vehicle
PHET—plug-in hybrid electric truck
PHEV—plug-in hybrid vehicle
PM—particulate matter
PM2.5—particulate matter ≤ 2.5 microns
PM10—particulate matter ≤ 10 microns
POS—point of sale
ppm—parts per million
ppb—parts per billion
PSI—Power Solutions International
PTR-MS—proton transfer reaction-mass spectrometry
RD&D—research, development and demonstration

## LIST OF ACRONYMS (cont'd)

RDD&D (or RD3)—research, development, demonstration and deployment
RFP—Request for Proposal
RFS—renewable fuel standards
RI—reactive intermediates
RNG—renewable natural gas
RTP/SCS—Regional Transportation Plan/Sustainable Communities Strategy
SAE—Society of Automotive Engineers
SB—Senate Bill
SCAB—South Coast Air Basin or "Basin"
SCAQMD—South Coast Air Quality Management District
SCFM—standard cubic feet per minute
SCE—Southern California Edison
SCR—selective catalytic reduction
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
SOAs—secondary organic aerosols
SoCalGas—Southern California Gas Company (A Sempra Energy Utility)
SULEV—super ultra-low emission vehicle
SUV—Sports Utility Vehicle
TAO—Technology Advancement Office
TAP— (Ports') Technology Advancement Program
TC—total carbon
TEMS—transportable emissions measurement system
THC—total hydrocarbons
TO—task order
tpd—tons per day
TRB—Transportation Research Board
TRL—technology readiness level
TSI—Three Squares, Inc.
TTSI—Total Transportation Services, Inc.
TWC—three-way catalyst
UCR—University of California Riverside
UCR/CE-CERT—UCR/College of Engineering/Center for Environmental Research & Technology
UCLA—University of California Los Angeles
UDDS—urban dynamometer driving schedule
$\mu g/m^3$—microgram per cubic meter
ULEV—ultra low emission vehicle
UPS—United Postal Service
U.S.—United States
U.S.EPA—United States Environmental Protection Agency
V2B—vehicle-to-building
V2G—vehicle-to-grid
V2G/B—vehicle-to-building functionality
VMT—vehicle miles traveled
VOC—volatile organic compounds
VPP— virtual power plant
WVU—West Virginia University
ZECT—Zero Emission Cargo Transport
ZEV—zero emissions vehicle


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