South Coast Air Quality Management District

30 YEAR ANNIVERSARY 1988 to 2018

Clean Fuels Program

MARCH 2018

2017 Annual Report & 2018 Plan Update

Technology Advancement Office

Leading the way to zero and near-zero emission technologies

Cover Photo Credits

Main Cover Photo:

- Fuel cell Class 8 truck – DOE ZECT Program

Top Row (left to right)

- Transit bus equipped with near-zero emission CNG Cummins 8.9L engine
- Battery electric school bus with vehicle-to-grid technology
- Hydrogen refueler for Class 8 trucks

Middle Row

- Near-zero emission CNG Cummins 8.9L engine
- Anaerobic digester – RNG production with SoCalGas pipeline injection
- DC fast charger for battery electric vehicles

Bottom Row

- Class 8 truck equipped with near-zero Cummins 11.9L engine operating on RNG
- Zero emission class 8 trucks
- Mobi: mobile auxiliary power and fast charger
- Battery electric Class 8 truck

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Orange County Cities

Executive Officer
Wayne Nastri

*Technology Committee Members **Technology Committee Chairman

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This year's Annual Report and Plan Update
is dedicated in remembrance of

Dr. Vernon P. Roan, Jr.

University of Florida, Professor Emeritus

Founding Member of the SB 98 Clean Fuels Advisory Group
Serving from 1999 to 2017,
As a scientific and academic community representative.

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South Coast Air Quality Management District

Technology Advancement Office

Matt Miyasato, Ph.D., Deputy Executive Officer, Science & Technology Advancement
Fred Minassian, Assistant Deputy Executive Officer, Technology Advancement Office
Naveen Berry, Technology Demonstration Manager
Vicki White, Technology Implementation Manager
Lourdes Cordova Martinez, Sr. Public Affairs Manager

Al Baez, Program Supervisor
Joseph Impullitti, Program Supervisor
Lisa Mirisola, Program Supervisor
Adewale Oshinuga, Program Supervisor
Walter Shen, Program Supervisor
Mei Wang, Program Supervisor
Vasken Yardemian, Program Supervisor

Tom Lee, Sr. Air Quality Engineer

Ash Nikravan, Sr. Staff Specialist

Jack Cheng, Staff Specialist

Philip Barroca, Air Quality Specialist
Lori Berard, Air Quality Specialist
Mark Coleman, Air Quality Specialist
Seungbum Ha, Air Quality Specialist
Patricia Kwon, Air Quality Specialist
Joseph Lopat, Air Quality Specialist
Krystle Martinez, Air Quality Specialist
Henry Pourzand, Air Quality Specialist
Greg Ushijima, Air Quality Specialist
George Wa, Air Quality Specialist

Kenneth Dudash, Air Quality Inspector II
Greta Grier, Air Quality Inspector II
Drue Hargis, Sr. Public Information Specialist

Penny Shaw Cedillo, Sr. Administrative Secretary
Pat Krayser, Sr. Administrative Secretary

Jennifer de la Loza, Secretary
Marjorie Eaton, Secretary
Donna Vernon, Secretary

Michelle White, Staff Assistant

Deanna Doerr, Contracts Assistant
Liliana Garcia, Contracts Assistant
Christina Kusnandar, Contracts Assistant
Frances Maes, Contracts Assistant
Mariel Maranan, Contracts Assistant
Genette Prudhomme, Contracts Assistant
Benigna Taylor, Contracts Assistant
Ana Troccoli, Contracts Assistant

Cynthia Snyder, Sr. Office Assistant

Tribrina Brown, Office Assistant

Other Staff Contributors
Michael Krause, Planning & Rules Manager
Michael Laybourn, Air Quality Specialist
Diana Thai, Air Quality Engineer II

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EXECUTIVE SUMMARY

Introduction

The South Coast Air Quality Management District (SCAQMD) 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 all of the South Coast Air Basin plus 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.

This year will mark the 30th year of the Clean Fuels Program, along with establishment of the Technology Advancement Office (TAO). It was in 1988 that 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. The Clean Fuels Program affords the SCAQMD the ability to fund research, development, demonstration and accelerated deployment of clean fuels and transportation technologies.

Using funding received through a $1 motor vehicle registration fee, the Clean Fuels Program has encouraged, fostered and supported clean fuels and transportation technologies, such as hydrogen and fuel cells, natural gas engines and infrastructure, battery electric vehicles, plug-in hybrid electric vehicles and related fueling infrastructure. A key strategy of the Program, which allows significant leveraging of the Clean Fuels funding (typically $3-$4 to every $1 of Clean Fuels funds), is its public-private partnership with private industry, technology developers, academic institutions, research institutions and government agencies. Further, while SCAQMD aggressively seeks to leverage funds to accomplish more with every dollar, it also strives to be a leader in technology development and commercialization 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 optimizes the region's ability to achieve the National Ambient Air Quality Standards (NAAQS).

Health & Safety Code (H&SC) 40448.5.1 requires the SCAQMD to prepare, and submit to the Legislative Analyst each year, 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. Preliminary review and comment by SCAQMD's Governing Board, advisory groups, technical experts and other interested parties are incorporated into the final Plan Update, along with the Clean Fuels Annual Report, which are due to the Legislative Analyst by March 31 of every year.

Setting the Stage

The overall strategy of TAO's Clean Fuels Program is based, in large part, on emission reduction technology needs identified through the Air Quality Management Plan (AQMP) process and the SCAQMD Governing Board's directives to protect the health of the approximately 17 million residents (nearly half the population of California) in the South Coast 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 SCAQMD Governing 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 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 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 health-based air quality standards. The 2016 AQMP projects that an approximate 45 percent reduction in NOx is required by 2023 and an additional 55 percent reduction by 2031. Figure 1 illustrates these needed NOx reductions in the South Coast Basin. The majority of these NOx reductions must come from mobile sources, both on- and off-road. Notably, the SCAQMD is currently only one of two regions in the nation designated as an extreme ozone nonattainment area (the other is San Joaquin Valley). 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 especially noteworthy because in the South Coast Air Basin the primary driver for ozone formation is NOx emissions, and mobile sources contribute approximately 88 percent of the NOx emissions in this region, as shown in Figure 2. 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 ($\mu g/m^3$)].

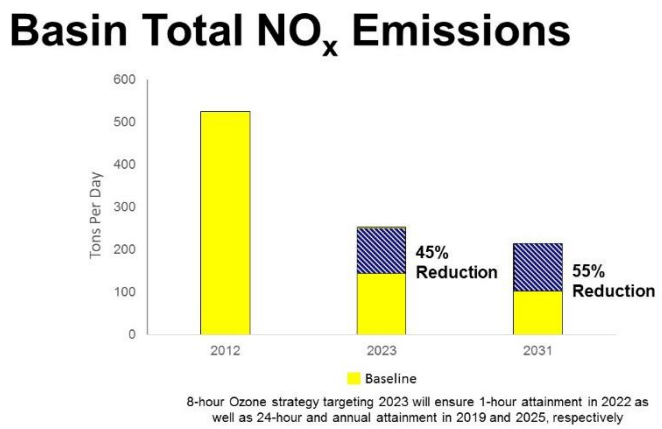


Figure 1: Total NOx Reductions Needed

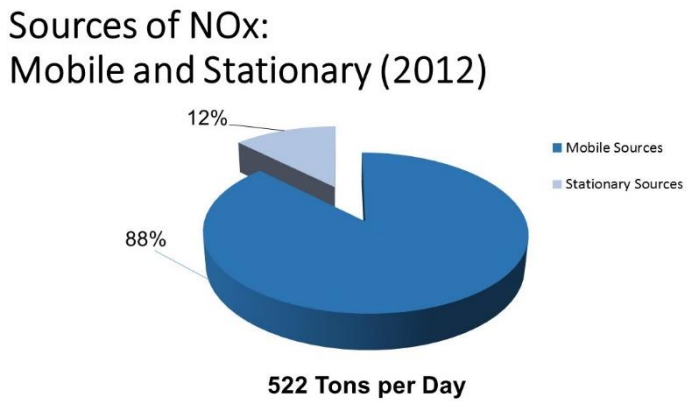
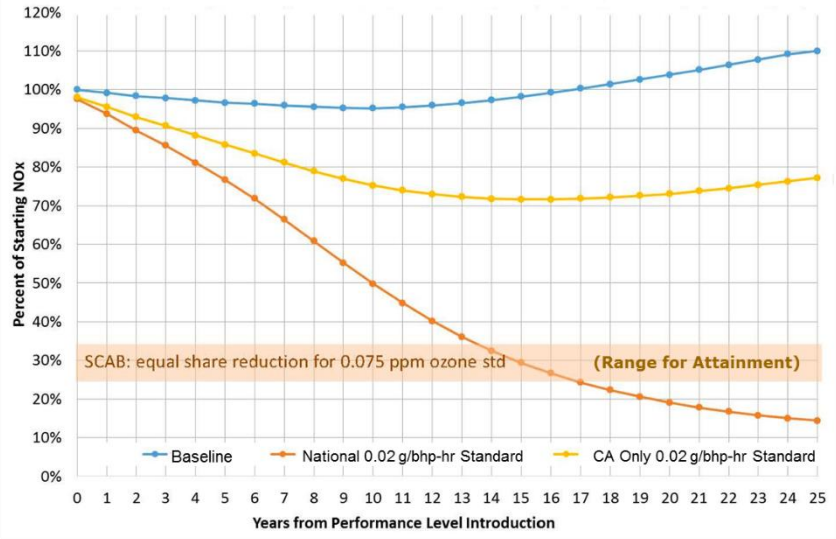


Figure 2: Sources of NOx 2012 Base Year

On a positive note, the 2016 AQMP for the first time envisions Southern California achieving attainment through regulations and incentives and identifies the clean technologies to be deployed that were formerly undefined as "blackbox" measures. This is due, in part, because the needed zero and near-zero technologies are being commercialized or nearing commercialization, albeit with deployment pathways that still require more specificity and scalability. Also, additional NOx and VOC emission reduction co-benefits are expected from carbon dioxide (CO2) reductions resulting from California's climate change policies, together with funding to incentivize the deployment of these cleaner technologies. There are significant challenges to attaining the air quality standards, however, including the need for the U.S. Environmental Protection Agency (U.S. EPA) and California Air Resources Board (CARB) to lower the heavy-duty engine exhaust NOx standard from 0.2 grams per brake horsepower-hour (g/bhp-hr) to an already commercially achievable (by natural gas powered engines) 0.02 g/bhp-hr.

Finally, financial resources will need to be identified that could be utilized to offset the higher procurement costs of these emerging clean technologies.

In June 2016, SCAQMD and 10 co-petitioners requested the U.S. EPA Administrator to undertake rulemaking to revise the national on-road heavy-duty engine exhaust NOx emission standard from 0.2 g/bhp-hr to 0.02 g/bhp-hr. It was recommended that the regulation be implemented by January 2022 or if not feasible, by January 2024, with a phase-in starting in January 1, 2022. A national standard (as opposed to only a California standard) is estimated to result in NOx emission reductions from this source category from 70 to 90 percent in 14 to 25 years, respectively. Given that the Basin must attain the 75 ppb ozone NAAQS by 2031 (within the next 13 years), a new on-road heavy-duty engine exhaust emissions standard for NOx is critical given the time needed for such standards to be adopted, for manufacturers to develop and produce compliant vehicles, and for national fleet turnover to occur.



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

Figure 3: NOx Reduction Comparison: No New Regulations vs Low NOx Standard in California only vs National Standard

Figure 3 (above-right) shows the difference in NOx reductions from heavy-duty trucks between baseline (i.e., no new regulations) emissions (in blue), a low NOx standard adopted only in California (yellow), and reductions if the same low NOx standard is implemented nationally (orange).

Clean Fuels Program

Due to these daunting challenges to reduce NOx and PM2.5 to meet health-based air quality standards, the Clean Fuels Program is more important than ever to encourage and accelerate the advancement and commercialization of clean fuel and transportation technologies.

Below is a brief summary of the contents of the 2017 Clean Fuels Program Annual Report and 2018 Plan Update. Every new Plan Update is reviewed by two advisory groups--the Clean Fuels Advisory Group and the Technology Advancement Advisory Group. These two groups meet approximately every six months to provide expert analysis and feedback on potential projects and areas of focus. They are also briefed and comment on the accomplishments of the prior year in the context of the annual report. The membership of these two bodies is in Appendix A. For more information on this review process, refer to Program Review (page 2). Further review of the Clean Fuels Program is detailed under Strategy and Impact (page 15).

2017 Annual Report

In CY 2017, the SCAQMD Clean Fuels Program executed 59 new contracts, projects or studies and modified 8 continuing projects adding dollars toward research, development, demonstration and deployment (RDD&D) projects as well as technology assessment and transfer of alternative fuel and clean fuel technologies. An additional 8 revenue agreements totaling $14.3 million were also executed. Table 2 (page 36) lists the 67 projects or studies, which are further described in this report. The SCAQMD Clean Fuels Program contributed nearly $17.9 million in partnership with other governmental organizations, private industry, academia and research institutes, and interested parties, with total project costs of more than $118.7 million. The $17.9 million includes $6.2 million recognized into the Clean Fuels Fund as pass-through funds from project partners to facilitate project administration by the Clean Fuels Program. Table 3 (page 39) provides information on this outside funding received into the Clean Fuels Fund. In addition, in CY 2017, the Clean Fuels Program continued to leverage other outside funding opportunities, securing new awards totaling $20.5 million from federal, state and local funding opportunities. Table 4 (page 40) provides a comprehensive summary of these federal, state and local revenues awarded to the SCAQMD during CY 2017. Similar to the prior year, the significant project scope of a few key contracts executed in 2017 resulted in higher than average leveraging of Clean Fuels dollars. Typical leveraging is $3-$4 for every $1 in Clean Fuels funding. In 2016, leveraging was $1:$9; in 2017, SCAQMD continued this upward trend with more than $6 leveraged for every $1 in Clean Fuels funds. Leveraging dollars and aggressively pursuing funding opportunities are more important than ever given the magnitude of additional funding identified in the 2016 AQMP to achieve federal ozone air quality standards.

The projects or studies executed in 2017 included a diverse mix of advanced technologies. The following core areas of technology advancement for 2017 executed contracts (in order of funding percentage) include:

1. Electric and Hybrid Vehicle Technologies and Related Infrastructure (emphasizing electric and hybrid electric trucks and container transport technologies with zero emission operations);
2. Fuels and Emission Studies;
3. Engine Systems/Technologies (emphasizing alternative and renewable fuels for truck and rail applications);
4. Hydrogen and Mobile Fuel Cell Technologies and Infrastructure;
5. Technology Assessment and Transfer/Outreach; and
6. Fueling Infrastructure and Deployment (predominantly natural gas and renewable fuels).

The pie chart on page 34 shows the distribution by percentage of executed agreements in 2017 across these core technologies.

During CY 2017, the SCAQMD supported a variety of projects and technologies, ranging from near-term to long-term RDD&D activities. This “technology portfolio” strategy provides the SCAQMD the ability and flexibility to leverage state and federal funding while also addressing the specific needs of the South Coast Air Basin (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 zero and near-zero emissions goods movement industry; fuels and emissions studies to conduct in-use testing and fuel characterization and usage profiles as well as evaluating strategies for reducing emissions in the goods movement sector; development, demonstration and deployment of large displacement natural gas engines; and continued demonstration and deployment of electric charging infrastructure; and natural gas and renewable natural gas deployment and support.

In addition to the 67 executed contracts and projects, 19 RDD&D projects or studies and 24 technology assessment and transfer contracts were completed in 2017, as listed in Table 5 (page 72). Appendix C comprises two-page summaries of the technical projects completed in 2017. As of January 1, 2018, there were 94 open contracts in the Clean Fuels Program; Appendix B lists these open contracts by core technology.

In accordance with California Health and Safety Code Section 40448.5.1(d), this annual report must be submitted to the state legislature by March 31, 2018, after approval by the SCAQMD Governing Board.

2018 Plan Update

Every year, staff re-evaluates the Clean Fuels Program to develop a Plan Update 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. The design and implementation of the Program Plan must balance the needs in the various technology sectors with technology readiness, emissions reduction potential and cofunding opportunities. As the state has turned a great deal of its attention to climate change and petroleum reduction goals, the SCAQMD has necessarily remained committed to developing, demonstrating and commercializing technologies that reduce criteria pollutants, specifically NOx. Fortunately many, if not the majority, of these technologies that address the Basin's need for NOx reductions also garner reductions in greenhouse gases (GHG) and petroleum use. Due to these "co-benefits," the SCAQMD 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 SCAQMD employs a number of 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 to solicit project ideas and concepts as well as issuance of Requests for Information (RFI) to determine the state of various technologies and the development and commercialization challenges faced by those technologies. For example, in 2016, an RFI was released to solicit information from diesel engine manufacturers and other entities to identify ultra-low NOx emission technology strategies that will result in commercially viable diesel engine technologies, capable of using renewable diesel for on-road heavy-duty vehicles such that they can achieve emission levels 90% below the current 2010 emission standards for NOx and reduce PM emissions to the greatest extent possible. Subsequently, in partnership with CARB and the Port of Los Angeles, staff initiated a project with Southwest Research Institute to develop advanced control systems to lower emissions from large displacement diesel engines, including under low-load and low-temperature conditions. Potential follow-up development, demonstration and certification projects resulting from this RFI are included conceptually within the Draft 2018 Plan Update.

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:

- reducing emissions from port-related activities, such as cargo handling equipment and container movement technologies, including demonstration and deployment of cargo container movement systems with zero emission range;
- 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 zero emission

technologies for high horsepower applications;
- mitigating criteria pollutant increases from renewable fuels, such as renewable natural gas, diesel and hydrogen as well as other renewable fuels and waste streams;
- developing and demonstrating electric-drive (fuel cell, battery, plug-in hybrid and hybrid) technologies across light-, medium- and heavy-duty platforms;
- producing transportation fuels and energy from renewable and waste stream sources; and
- establishing large-scale hydrogen refueling and EV charging infrastructures to help accelerate the introduction zero emission vehicles into the market.

Table 6 (page 89) lists the potential projects across nine core technologies by funding priority:

1. Hydrogen and Mobile Fuel Cell Technologies and Infrastructure;
2. Engine Systems/Technologies (emphasizing alternative and renewable fuels for truck and rail applications);
3. Electric and 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. Fuel and Emissions Studies;
6. Technology Assessment and Transfer/Outreach;
7. Stationary Clean Fuels Technologies (including renewables);
8. Emission Control Technologies; and
9. Health Impacts Studies.

These potential projects for 2018 total $16.7 million, with anticipated leveraging of more than $4 for every $1 of Clean Fuels funding for total project costs of nearly $70 million. Some of the proposed projects may also be funded by revenue sources other than the Clean Fuels Program, especially VOC and incentive projects.

CLEAN FUELS PROGRAM
Background and Overview

Program Background

The South Coast Air 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 all of the South Coast Air Basin plus small portions of the Mojave Desert and Salton Sea Air Basins, is home to approximately 17 million people (nearly half the population of California). Due to these confluence of factors which present unique challenges, the state legislature enabled the SCAQMD to implement the Clean Fuels Program to accelerate the implementation and commercialization of clean fuels and advanced mobile source technologies.

In fact, this year will mark the 30th year of the Clean Fuels Program, along with establishment of the Technology Advancement Office (TAO). It was in 1988 that 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.

In 1999, further state legislation was passed which amended the Clean Fuels Program. Specifically, as stated in the California Health and Safety Code (H&SC) section 40448.5.1(d), the SCAQMD 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 SCAQMD 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 SCAQMD'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 SCAQMD;
3. A description of projects funded by the SCAQMD, 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 SCAQMD 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.

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

Program Review

In 1990, the SCAQMD initiated an annual review of its technology advancement program by an external panel of experts. That external review process has evolved, in response to SCAQMD policies and legislative mandates, into two external advisory groups. The Technology Advancement Advisory Group (one of six standing Advisory Groups that make up the SCAQMD 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 SCAQMD 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 SCAQMD Governing Board. Also in 1999, in light of the formation of the SB 98 Clean Fuels Advisory Group, the SCAQMD 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 SCAQMD Board while changes to the Technology Advancement Advisory Group are reviewed by the SCAQMD Board's Technology Committee. Current membership changes to both advisory groups, if required, will be considered by the SCAQMD Board and its Technology Committee, respectively, as part of consideration of the 2017 Annual Report and 2018 Plan Update. The current members of the SB 98 Clean Fuels Advisory Group and Technology Advancement Advisory Group are listed in Appendix A, with any proposed changes, subject to SCAQMD Board approval, duly noted.

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 SCAQMD Governing Board; 5) a public hearing of the Annual Report and Plan Update before the full SCAQMD Board, along with adoption of a 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 & Clean 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. The need for advanced mobile source technologies and clean fuels is best illustrated by Figure 1 below, which identifies just how far NOx emissions must be reduced to meet federal standards by 2023 and 2031.

To fulfill long-term emission 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 (80 ppb, 8-hour average) and fine particulate matter, promulgated by the U.S. EPA in 1997 and 2006, are projected to require additional long-term control measures for both NOx and VOC. The 2016 AQMP's estimate of needed NOx reductions will require the SCAQMD Clean Fuels Program to encourage and accelerate advancement of clean transportation technologies that are used as control strategies in the AQMP.

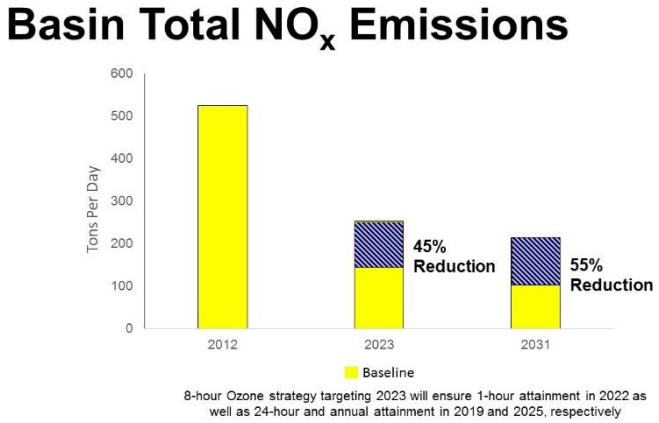


Figure 1: Total NOx Reductions Needed

Health studies also indicate a greater need to reduce NOx emissions and toxic air contaminant emissions. For example, the goal of SCAQMD'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 2017, SCAQMD 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 typically emitted or converted from vehicle exhaust.

The emission reductions needed for this region are outlined further in CARB's draft "Mobile Source Strategy" (May 2016)[1], which is an integrated plan to transform California's mobile sector. Specifically, it calls for California to build upon its successful efforts to meet critical air quality and climate goals, as summarized below:

- Attaining federal health-based air quality standards for ozone in 2023 and 2031 in the South Coast and San Joaquin Valley, and fine particulate matter (PM2.5) standards in the next decade;
- Achieving GHG emission reduction targets of 40 percent below 1990 levels by 2030;
- Reducing our petroleum use by up to 50 percent by 2030;
- Minimizing health risk from exposure to toxic air contaminants; and
- Increasing energy efficiency and deriving 50 percent of our electricity from renewable sources by 2030.

The CARB document focuses on mobile sources, both on- and off-road equipment, that are responsible for approximately 80 percent of smog-forming NOx emissions, 95 percent of diesel particulate matter emissions and 50 percent of GHG emissions in California. In the South Coast Air Basin the primary

[1] https://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf

driver for ozone formation is NOx emissions, and mobile sources contribute approximately 88 percent of the NOx emissions in this region, as shown in Figure 2. Given this contribution, significant cuts in pollution from these sources are needed, therefore the proposed mobile source strategy calls for establishing requirements for cleaner technologies (both zero and near-zero) and deploying these technologies into the fleet, requiring cleaner and renewable fuels, and ensuring continued clean performance in use. Actions to accelerate the deployment of cleaner technologies through incentives, efficiency increases in moving people and freight, and support for the use of advanced transportation technologies such as intelligent transportation systems and autonomous vehicles, are also needed. Taken together, these actions would provide the reductions necessary from mobile sources to achieve the air quality and climate goals outlined above.

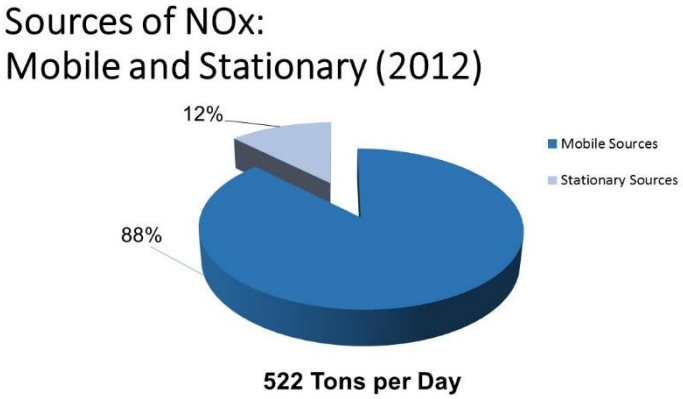


Figure 2: Sources of NOx 2012 Base Year

Subsequently, in November 2016, CARB released a revised draft of the Short Lived Climate Pollutant strategy to address emissions from methane, black carbon and hydrofluorocarbons (HFCs). And in 2017, an updated California Sustainable Freight Action Plan[2] (CSFAP) incorporating pilot projects was released. The CSFAP outlines a transition to a more efficient, economically competitive, and cleaner freight transport system.

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 SCAQMD's jurisdiction; to reduce long-term dependence on petroleum-based fuels; and to support a more sustainable energy future. Conventional strategies and traditional supply and consumption need to be retooled in order to achieve the federal air quality goals. To help meet this need for advanced, clean technologies, the SCAQMD Board continues to aggressively carry out the Clean Fuels Program and promote alternative fuels through its Technology Advancement Office.

The Clean Fuels Program is intended to assist in the accelerated development and deployment of progressively lower-emitting technologies and fuels through innovative public-private partnership. Since its inception, SCAQMD's TAO has cofunded projects in cooperative partnerships with private industry, technology developers, academic and research institutions and local, state and federal agencies. The following sections describe program funding, provide a 2017 overview and describe core technologies of the Clean Fuels Program.

Program Funding

The Clean Fuels Program is established under California 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

[2] http://www.casustainablefreight.org/

previous cap of two-and-half percent.

Specifically, the Program is funded through a $1 fee on motor vehicles registered in the SCAQMD. 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 SCAQMD. For CY 2017, the funds available through each of these mechanisms were as follows:

- Mobile sources (DMV revenues) $13,610,601
- Stationary sources (emission fee surcharge) $330,224

The SCAQMD Clean Fuels Program also receives grants and cost-sharing revenue contracts from various agencies, on a project-specific basis, that supplement the SCAQMD program. Historically, such cooperative project funding revenues have been received from CARB, the CEC, the U.S. EPA, 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 39) lists the supplemental grants and revenues totaling $6.2 million for contracts executed in CY 2017.

Table 4 (page 40) lists the federal and state revenue totaling nearly $20.5 million awarded to the SCAQMD in 2017 for projects that will be part of the Clean Fuels Program or align well and complement the Clean Fuels Program.

The final and perhaps most significant funding source can best be described as an indirect source, i.e., funding not directly received by the SCAQMD. This indirect source is the cost-sharing provided by private industry and other public and private organizations. Historically, the Technology Advancement Office has been successful in leveraging its available public funds with $3 to $4 of outside funding for each $1 of SCAQMD funding. For 2017, the Clean Fuels Program leveraged each $1 to more than $6 of outside funding. Similar to last year, this atypical leverage was the result of a few key contracts with significant project scopes executed in 2017, such as the $23 million award from CARB's California Climate Investment Program (see Table 2 for more information on these key projects). Through these public-private partnership, the SCAQMD 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 SCAQMD aggressively seeks leverage funds to accomplish more with every dollar, it also strives to be a leader in technology development and commercialization in an effort 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 the magnitude of additional funding identified in the 2016 AQMP to achieve federal ozone air quality standards. The SCAQMD'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 2017 are listed in Table 1 (page 16).

2017 Overview

This report summarizes the progress of the SCAQMD Clean Fuels Program for CY 2017. The SCAQMD Clean Fuels Program cosponsors projects to develop and demonstrate zero, near-zero and low emission clean fuels and advanced technologies and to promote commercialization and deployment of promising or proven technologies in Southern California. 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 SCAQMD Clean Fuels Program in CY 2017. During the period between January 1 and December 31, 2017, the SCAQMD executed 59 new contracts, projects or studies and modified 8 continuing projects adding dollars during CY 2017 that support clean fuels and advanced zero, near-zero and low emission technologies. The SCAQMD Clean Fuels Program contribution for these projects was approximately $17.9 million, inclusive of $6.2 million received into the Clean Fuels Fund as cost-share for contracts executed in this reporting period. Total project costs exceed $118.7 million. These projects address a wide range of issues with a diverse technology mix. 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 39), but also funds awarded to the SCAQMD for projects to be included in the Clean Fuels Program or which align well and are complementary to the Clean Fuels Program ($20.5 million in 2017, see Table 4). More details on this financial summary can be found later in this report. The SCAQMD will continue to pursue federal, state and private funding opportunities in 2018 to amplify leverage, while acknowledging that support of a promising technology is not contingent on outside cost-sharing and affirming that SCAQMD will remain committed to being a leader 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 of 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 and Fuel Cell Technologies and Infrastructure (especially large-scale refueling facilities)
- Engine Systems/Technologies (emphasizing heavy-duty alternative and renewable fuel engines for truck and rail applications)
- Electric and Hybrid Vehicle Technologies and 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)
- Fuels and Emissions Studies
- Technology Assessment and Transfer/Outreach
- Stationary Clean Fuels Technologies
- Emission Control Technologies
- Health Impacts Studies

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

1. Low, near-zero and zero 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 SCAQMD 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 SCAQMD program is significant, national and international activities affect the direction of

technology trends. As a result, the SCAQMD program must be flexible in order to leverage and accommodate these changes in state, national and international priorities. Nonetheless, while the state and federal governments have in recent years turned a great deal of their attention to climate change, SCAQMD 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 SCAQMD has been successful in partnering with the state and federal government. Even with the leveraged funds, the challenge for the SCAQMD 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 SCAQMD will need to continue to employ a number of outreach and networking activities as well as evaluate new ways to expand these activities. Typical activities range from intimate involvement with state and federal collaboratives, partnerships and industrial coalitions, to the issuance of Program Opportunity Notices to solicit project ideas and concepts as well as the issuance of Requests for Information to determine the state of various technologies and the challenges faced by those technologies for commercialization. While employing a number of creative outreach and networking activities to try to overcome these challenges, SCAQMD's TAO annually develops a comprehensive plan to encourage and accelerate the development and demonstration of cleaner technologies. Every year TAO staff re-evaluates the Clean Fuels Program to develop a comprehensive plan (referred to as the 2017 Plan Update within this document) to essentially re-assess the technology progress and direction for the agency.

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 power-trains 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 on recent years has been on zero and near-zero emission technologies 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 SCAQMD 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.

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 SCAQMD programs that meet both the funding constraints as well as 2016 AQMP needs for achieving clean air are briefly described below.

Hydrogen and 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 numerous others have plans to commercialize their own in the near future. 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 production of a plug-in fuel cell model GLC for 2018, with U.S. availability approximately late 2019. 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 2017, partially funded by SCAQMD for those in our region, there are five non-retail and 31 retail operational in California, but most if not all 65 are expected to be operational by the end of 2019 with capacity for more than 10,000 fuel cell vehicles. AB 8 also requires CARB to annually assess current and future FCVs and hydrogen stations in the marketplace. *The Joint Agency Staff Report on Assembly Bill 8: 2017 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California*[3] released in December 2017 reporting on 2017 findings states that there were 2,473 fuel cell vehicles registered in California by October 2017. However, CARB's 2017 Annual Evaluation projects 13,400 FCEVs in California by 2020 and 37,400 by the end of 2023. Clearly, the SCAQMD must continue to support the infrastructure required to refuel retail fuel cell vehicles. To that end, SCAQMD is also actively engaged in finding alternatives to reducing the cost of hydrogen (e.g., large-scale hydrogen refueling stations) and potential longer term fuel cell power plant technology.

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 of the on-road mobile source PM2.5, a known toxic air contaminant. Furthermore, according to CARB, trucks and buses are responsible for 37 percent of California's greenhouse gases and criteria emissions. These figures notably do not include the significant contribution from off-road mobile sources, which contribute significantly to NOx and PM2.5 emissions in the Basin. Furthermore, 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.

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 SCAQMD, 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 transport trucks, transit and school buses, rail operations, and refuse collection and delivery vehicles to meet future federal emission standards.

In connection with the challenge to develop cleaner engine systems, on June 3, 2016, the EPA received a Petition, led by SCAQMD and joined by many other state air quality management agencies, to initiate rulemaking guidelines to create a national standard for ultra-low NOx heavy-duty engines. The 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. The EPA has initiated action towards proposed rulemaking for a revised heavy-duty NOx program, with the intent of proposing standards that could begin model year 2024, consistent with the lead-time requirements of the Clean Air Act and the AQMP goals. If EPA adopts a more stringent heavy-duty NOx standard for the nation, engine manufacturers will be required to step up further to develop cleaner engines, and this region will also benefit from cleaner vehicles coming into the state as part of the goods movement industry.

[3] http://www.energy.ca.gov/2017publications/CEC-600-2017-011/CEC-600-2017-011.pdf

Electric and 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 passenger vehicles and more recently plug-in electric vehicles (PEVs) by almost all of the automakers and increased public attention on global warming, as well as several Executive Orders issued by Governor Brown over the last couple of years. The Governor's most recent Executive Order, which was issued on January 26, 2018, calls for 5 million ZEVs by 2030.

The growing awareness by both government and the public for the need for better air quality is leading to stricter emissions targets and a demand for greater fuel efficiency for vehicles. As a result, there is now a window of opportunity to leverage state and federal activities in the development and deployment of technologies that can accelerate advanced electric and hybrid technologies, including medium- and heavy-duty hybrid vehicle deployment, energy storage technologies and other power options, development of medium- and heavy-duty hybrid emission certification cycles, battery durability testing and establishment of driver use patterns. Such technology developments, if successful, are considered enabling because they can be applied to a variety of fuels (e.g., gasoline, natural gas, biofuels and hydrogen) and propulsion systems - e.g., internal combustion engines (ICEs), batteries and fuel cells. In particular, utilizing electric drive technologies to enable zero emission mile capable heavy-duty trucks for goods movement remains a top priority.

EV adoption surpassed a huge milestone in 2107, selling more than 360,000 cumulative electric vehicles in California, according to Veloz (formerly the PEV Collaborative), with increasingly more announcements by international automakers (e.g., Mercedes-Benz, Volkswagen-Audi-Porsche and several growing Chinese brands) on a variety of electrification plans, including some with extended zero emission range. Joining the trend with Tesla Model 3 to longer electric ranges and faster charging, the 2017 Chevy Bolt EV, with an estimated EPA range of 238 miles and an affordable price after incentives, was a best seller. However, in order to achieve the fleet penetration required for clean air, the need for charging infrastructure is significant. One sign of progress in this area is last year's California Public Utility Commission action recognizing the need for transportation electrification and approving Southern California Edison's (SCE's) $22 million "Charge Ready" pilot program to support installation of as many as 1,500 EV charging stations in their service territory. The SCAQMD will work with SCE to identify the best strategy for EV infrastructure (e.g., destination and residential charging) to complement this new program and continue to work with CEC, other government agencies and private entities to implement installation of charging infrastructure in our region. In January 2018, SCE detailed plans for four pilot programs aimed at accelerating the electrification of the state's transportation, with half the projects focused on fleet and heavy-duty uses. SCAQMD plans to closely follow the progress of these pilot programs to determine how they might mesh with our own programs.

Fueling Infrastructure and Deployment (NG/RNG)

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% by 2020 and 50% by 2030 as required by SB 350 (chaptered October 2015), the objectives of the SCAQMD 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 and renewable natural gas (RNG) infrastructure and deployment (electric and hydrogen fueling are included in their respective technology categories). Changes to the Carl Moyer Program as a result of SB 513 (chaptered October 2015) may help stimulate deployment of alternative and natural gas vehicles and related infrastructure. The Clean Fuels Program will continue to examine opportunities where current incentive funding is either absent or insufficient. Market offerings such as Ford's 2016 F-150 which has the ability to run on natural gas may help further spur demand in this area.

Health Impacts, Fuel and Emissions Studies

The monitoring of pollutants in the Basin is extremely important, especially when focused on (1) a particular 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. Considering the transition to alternative and renewable fuels, accelerated by federal and state requirements, 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 emission 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, especially in the heavy-duty sector, as well as light- and heavy-duty engines that operate on renewable fuels or higher compression spark- ignited 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.

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 near zero-emission technologies, such as solar, 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. 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.

Emission 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 the majority of 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 non-road mobile sources lies primarily with the U.S. EPA and CARB.

Low-emission and clean-fuel technologies that appear promising for on-road mobile sources should be effective at reducing emissions from a number of non-road sources. For example, immediate benefits are possible from particulate traps and selective catalytic reduction (SCR) that have been developed for diesel applications. Clean fuels such as natural gas, propane, hydrogen and hydrogen-natural gas mixtures may also provide an effective option to reduce emissions from some non-road applications. 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.

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 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 fuels technologies, and coordination of these activities with other organizations. Technology transfer efforts also include support for various clean fuel vehicle incentive programs. The other spectrum of this core technology is information dissemination to educate the end user and increase awareness. While SCAQMD's Public Affairs office oversees and carries out the majority of such education and awareness efforts on behalf of the entire agency, TAO cosponsors and occasionally hosts various technology-related events to complement their efforts. These efforts range from general outreach and partnerships to convening or cosponsoring events. Some examples include: 1) partnerships with local colleges such as Cal State Los Angeles' Hydrogen Research and Fueling Facility; 2) SCAQMD's A World We Can Change high school conferences; 3) participation in the Jet Propulsion Laboratory's Annual Climate Day for middle schoolers promoting STEM education; 4) partnerships for national events such as Drive Electric Week; and 5) hosting tours of SCAQMD's clean fuel vehicle fleet and their respective fueling platforms.

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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 SCAQMD 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 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.

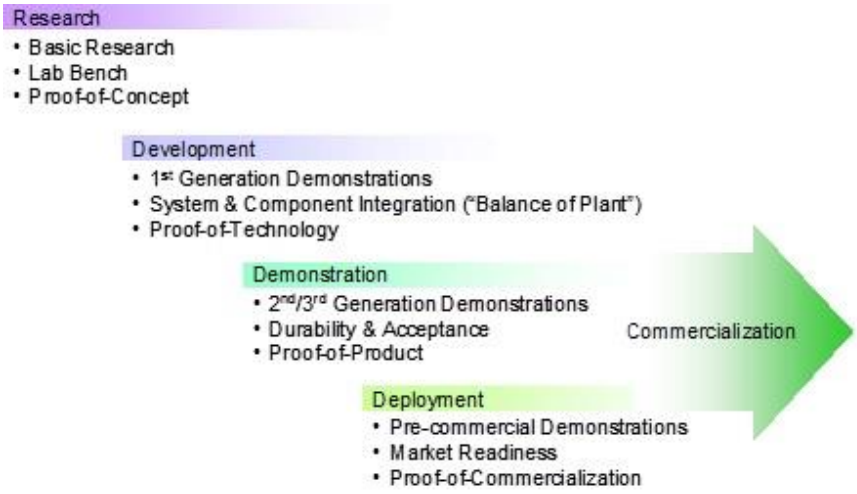


Figure 3: Stages of Clean Fuels Program Projects

Due to the nature of these advanced technology research, development, demonstration and deployment projects, the benefits are difficult to quantify since their full emission 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.

- CNG 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);
  - Detroit Diesel: Series 60G (CNG/LNG), Series 50G (CNG/LNG); and
  - Clean Air Partners/Power Systems (Caterpillar): 3126B (Dual Fuel), C-10 (Dual Fuel), C-12 (Dual Fuel).
- Fuel Cell Development and Demonstrations
  - Ballard Fuel Cell Bus (first of its kind);
  - Retail light-duty passenger fuel cell vehicles (Toyota Mirai, Hyundai Tucson, Honda Clarity);
  - SunLine Transit Agency Advanced Fuel Cell Bus projects;
  - Commercial stationary fuel cell demonstration with UTC and SoCalGas (first of its kind);
  - Orange County Sanitation District hydrogen and combined heat and power generation from biogas using molten carbonate fuel cell technology (as well as their renewable hydrogen station);
  - New Flyer and El Dorado Transit Bus at OCTA;
  - 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
  - Plug-in Hybrid Electric Van with EPRI, DaimlerChrysler and SCE;
  - Hybrid electric delivery trucks with NREL, FedEx and UPS;
  - Proterra battery electric transit bus and fast charging system;
  - Municipal battery electric utility truck;
  - South Bay City Council of Governments' electric vehicle project;
  - EVI/UPS electric truck;
  - Plug-in hybrid work truck with Odyne Systems;
  - Plug-in hybrid van and pickup with VIA Motors;
  - BYD all-electric transit bus and trucks (yard hostlers and drayage);
  - LACMTA battery electric buses;
  - Electric school buses, including V2G capability;
  - TransPower/US Hybrid battery electric heavy-duty truck and yard hostlers; and
  - PACCAR (Kenworth and Peterbilt) battery-electric and plug-in hybrid 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 medium-duty diesel engines

SCAQMD 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 research, development, demonstration and deployment process.

Strategy and Impact

In addition to the feedback and input detailed in Program Review (page 2), the SCAQMD 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 SCAQMD 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, National Association of Fleet Administrators (NAFA), major local transit districts and local gas and electric utilities. The list of organizations with which the SCAQMD coordinates research and development activities also includes organizations specified in H&SC Section 40448.5.1(a)(2).

In addition, the SCAQMD holds periodic meetings with several organizations specifically to review and coordinate program and project plans. For example, the SCAQMD 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 California Fuel Cell Partnership (CaFCP), the California Stationary Fuel Cell Collaborative, the California Natural Gas Vehicle Partnership (CNGVP), the California Hydrogen Business Council (CHBC), the Electric Power Research Institute (EPRI), the SoCalEV Collaborative and the West Coast Collaborative, which is part of the National Clean Diesel Campaign. The coordination efforts with these various stakeholders have resulted in a number of cosponsored projects.

Descriptions of some of the key contracts executed in CY 2017 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 SCAQMD 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 SCAQMD program. These partners are identified in the more detailed 2017 Project Summaries (beginning page 41) contained within this report.

Table 1: SCAQMD Major Funding Partners in CY 2017

Research Funding Organizations	**Major Manufacturers/Providers**
California Air Resources Board	BYD Motors Inc.
California Energy Commission	Cummins Westport, Inc.
National Renewable Energy Laboratory	Hydrogenics USA Inc.
Department of Energy	Kenworth Truck Company
Department of Transportation	North American Repower LLC
U.S. Environmental Protection Agency	Peterbilt Motors
West Virginia University Research Corporation	Ports of Los Angeles & Long Beach
Local Air Districts & Utilities	Odyne Systems, LLC
Bay Area AQMD	Orange County Transportation Authority
San Diego APCD	University of California Riverside/ CE-CERT
San Joaquin APCD	VeRail Technologies Inc.
Southern California Edison	Volvo Technology of America LLC
Southern California Gas Company	
San Diego Gas & Electric/Sempra Energy	

The following two subsections broadly address the SCAQMD's impact and benefits by describing specific examples of accomplishments including commercial or near-commercial products supported by the Clean Fuels Program in CY 2017. 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 SCAQMD research and development coordination efforts in 2017 include: (a) the California Collaborative Advanced Technology Drayage Truck Demonstration (b) Development and Demonstration of Medium-Duty (Class 5-7) Plug-In Hybrid Electric Vehicles (PHEVs) for Work Truck Applications; (c) Development and Demonstration of Ten Transit Fuel Cell Buses; and (d) Development of Retrofit Technology for Natural Gas Engines and In-Use Emissions Testing of On-Road Heavy-Duty Trucks.

California Collaborative Advanced Technology Drayage Truck Demonstration

The SCAQMD and the other four large air districts in the state[4] jointly partnered to develop the most commercially promising zero and near-zero emissions drayage truck technologies. Guided by extensive commercialization research, the partnership successfully engaged three major U.S. original equipment manufacturers' (OEMs), an international OEM leader in heavy-duty electrification, and two of the foremost zero emission technology integrators in order to leverage past success to drive true product development stages in a targeted portfolio of zero emission and near-zero emission technologies and increased efficiency solutions. These vehicles will support the diverse geographic and operational challenges across the state's interconnected goods movement system and include: 1) plug-in battery-electric trucks (BYD and Peterbilt-TransPower), 2) natural gas range-extended electric with plug-in charging trucks (Kenworth-BAE), and 3) plug-in diesel hybrid electric with ITS (Volvo). This exceptional portfolio features demonstrations of truly commercial pathway trucks with some of the largest goods movement service providers. This is significant because major OEMs can bring necessary engineering resources, manufacturing capability and a distribution-service network to support the future commercialization of these demonstration vehicles. The partnership also includes Los Angeles County Metro's participation with ITS efficiency integration, electric utility participation, and 13 confirmed end-user fleets experienced with the specific challenges and opportunities associated with early technology integration efforts. Each air district is committing staffing, significant cost-share, and fleet demonstration oversight to support this groundbreaking commercialization initiative, as everyone collectively pools resources to validate and drive to market economically viable solutions to the criteria pollutant and GHGs associated with drayage truck and goods movement operations throughout the state.

The collective experience has shown that there is no "silver-bullet" zero emission technology solution, and each air district faces highly individualized drayage economies and operational challenges. The SCAQMD needs drayage technologies capable of meeting the localized work in the Ports of Long Beach and Los Angeles and also technologies that can complete roundtrips to the warehousing centers throughout the Inland Empire. The BAAQMD needs technologies to support operations in and around the Port of Oakland, and also operations that connect the Port with the Central Valley. The SDAPCD is targeting demonstration efforts on port-specific and highly localized local operations, though these same fleets operate throughout Southern California. The SJVAPCD supports operations in and around the Port of Stockton, in addition to significant goods movement traffic that connects to other air districts along the I-5 corridor, with approximately 45% of all of the truck traffic within the state's four major trade corridors occurring within the San Joaquin Valley. For both SJVAPCD and SMAQMD, unique circumstances, such as distances and bordering mountain passes, pose challenges for the adoption of pure zero emission technologies.

In order to rapidly commercialize a commercially viable mix of the most promising Class 8 drayage technologies for the California marketplace, this collaborative project will: 1) build class 8 products based on existing battery-electric, plug-in hybrid and range-extender truck technologies; 2) integrate cooperative intelligent transportation system (C-ITS) and efficiency innovations into a near-zero emission truck product; 3) work with experienced, confirmed early-adopter fleets throughout the state to demonstrate and optimize product offerings; and 4) facilitate large-scale knowledge and technology transfer via new and expanded partnerships with the nation's foremost heavy-duty OEMs and zero emission technology developers:

[4]Bay Area Air Quality Management District (BAAQMD), Sacramento Metropolitan Air Quality Management District (SMAQMD), San Diego Air Pollution Control District (SDAQMD) and San Joaquin Valley Air Pollution Control District (SJVAPCD)

- BYD will develop a 100% battery-electric drayage truck that is optimized to serve near-dock and short regional drayage routes. BYD is a global company with over $9 billion in revenue and 180,000 employees, including manufacturing in Lancaster, CA. BYD's clean energy division produces battery storage stations, solar panels and LED lights. In 2003, BYD entered the automotive market and is now the largest selling domestic car manufacturer in China. Their global market strategy is focused on electric transportation, and BYD is the global leader in electric bus and taxi sales, with 5,000 orders in each segment, and trucks are its emerging segment. BYD will develop 25 vehicles under this project.

Figure 4: BYD Battery-Electric Drayage Truck

- Peterbilt, part of the PACCAR Group, has partnered with TransPower to develop two 100% battery-electric drayage truck products for this project, one with an 80-mile range focused on near-dock drayage routes (eight trucks) and an extended-range battery electric truck with a 200 mile range (four trucks) to help serve longer drayage routes, such as Southern California's Inland Empire and routes from the Port of Oakland into Sacramento and the San Joaquin Valley. In 2013, PACCAR achieved 28% of the Class 8 retail market share in the U.S. and Canada. And over the past five years, TransPower has established itself as a zero emission leader, successfully deploying more working, zero emission drayage trucks into actual real-world service in California than any other company.

Figure 5: Peterbilt Electric Truck

- Kenworth, also part of the PACCAR Group, expands its BAE Systems partnership to develop four natural gas range-extended electric trucks that leverage the prototype development under the SCAQMD and DOE ZECT II Program. These vehicles will target longer regional drayage routes, which Kenworth believes will include other regional heavy-haul markets. Kenworth ended 2014 with 14.5% heavy-duty market share for the U.S. and Canada, and BAE systems is a global defense and security company with approximately 100,000 employees worldwide. Its HybriDrive® Systems is a world leader in hybrid electric propulsion technology solutions for the transit bus industry.

Figure 6: Kenworth CNG Hybrid Truck

- Volvo is building on their PHEV diesel hybrid Class 8 truck developed under a SCAQMD and DOE grant. Volvo will continue refinement towards commercialization, including integration of innovative and significant C-ITS efficiency measures, in cooperation with Los Angeles

Figure 7: Volvo Diesel Hybrid Drayage Truck

County Metro. The Volvo Group's combined market share for North American heavy-duty trucks amounts to more than 20%. Volvo will develop two trucks under this project but move through several critical internal product development "gates."

The foundation of this project is formalizing the partnership connecting OEMs that have significant engineering, distribution and service and customer resources with the most promising zero and near-zero technology developers. The stateside district partners leveraged their expertise in successful drayage grant and advanced technology rollouts to engage fleet partners who can demonstrate these technologies in a range of drayage operations. This uniquely collaborative project also welcomes stakeholders such as Los Angeles County Metro to help demonstrate innovative approaches to efficiency with traffic management using C-ITS. Two utilities - Southern California Edison and San Diego Gas & Electric (SDG&E) - are committed to the EVSE planning and implementation efforts to support plug-in charging needs, with SDG&E providing direct cost-share to demonstrate and assess scalable EVSE support. Another partner, Calstart Inc., will help assess expanded markets and next stage deployments to help assist the move to full production.

Development and Demonstration of Medium-Heavy Duty (Class 5-7) PHEVs for Work Truck Applications

The work-truck segment is almost exclusively made up of medium- and heavy-duty vehicles, and is responsible for creating a disproportionate amount of emissions in the South Coast region since they represent a relatively small percentage of the vehicle population, yet are responsible for significant NOx and PM emissions, especially localized emissions within residential neighborhoods. The hybridization and electrification of vehicles in this segment provides one such opportunity to reduce criteria pollutant and greenhouse gas emissions. Additionally, eliminating the need for idling, especially in residential communities, minimizes localized exposure and noise issues.

Figure 8: Medium-Heavy Duty Plug-in Hybrid Work Truck Applications

Earlier development efforts funded by the American Recovery and Reinvestment Act have yielded the first generation modular PHEV system that can be installed on new and retrofit vehicles. In an effort to further lower emissions and improve performance via system optimization, Odyne was awarded $2.9 million from the Department of Energy for further development of existing technology. Odyne partnered with the SCAQMD, Freightliner Trucks, Allison Transmission, National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL), Duke Energy, Sempra Energy, AVL and LG Chem to design, develop and demonstrate a new generation of medium-heavy duty (Class 5-7) PHEV work truck that achieves a significant reduction in fuel consumption versus a conventional vehicle baseline. The plug-in hybrid technology includes idle reduction, launch assist, regenerative

braking, in-cab climate controls and exportable power, improving vehicle efficiency while driving and eliminating idling and emissions during operation at a jobsite. This project will address significant improvements in powertrain integration and adaptive control, a higher level of hybridization, fully electric jobsite operation and low cost modular battery pack solution through integrated three development streams into a final vehicle.

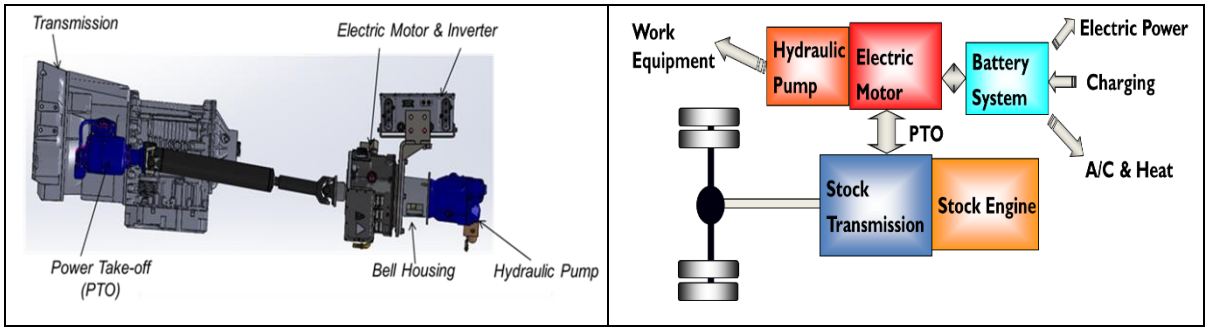


Figure 9: Odyne Power Take-Off (PTO) System

The primary objectives of this project are:

- To improve the hybrid driving mode of the existing Odyne's PHEV system with a targeted improvement of 50% fuel economy gain when compared to a conventional work truck.
- To improve the base cost of the existing system through the development and integration of a modular lithium-ion battery pack based on automotive light duty cells.
- To optimize the system and selected powertrain components for high volume production to enhance commercial appeal through lower-cost products and components.
- To quantify improvements in fuel economy and emissions. The project will gather vehicle and component performance data during deployment that will enable the operating cost and environmental impact of the vehicle to be assessed.

This hybridization of transportation technologies has the potential to lower criteria pollutant emissions and reduce GHGs. This can provide substantial air quality benefits to communities, neighborhoods and schools where these vehicles operate.

Development and Demonstration of Ten Fuel Cell Transit Buses

The SCAQMD has identified the development and deployment of zero emission transit buses as one of the key strategies towards attaining the federal air quality standards, as well as the technology transfer potential to other heavy-duty vehicles including drayage trucks. This is consistent with the goods movement strategy for zero emission technologies and infrastructure in heavy-duty vehicle categories proposed in SCAQMD's 2016 Air Quality Management Plan, SCAG's 2016 *Regional Transportation Plan* as well as the joint CARB, SCAQMD and SJVAPCD *Vision for Clean Air: A Framework for Air Quality and Climate Planning*. Zero emission transit bus deployment is proposed through the year 2040 to meet goals outlined in the 2016 *Regional Transportation Plan/Sustainable Communities Strategy*.

As part of a $45 million development and demonstration project, the Center for Transportation and the Environment (CTE) was awarded a $22 million grant from CARB through its Low Carbon Transportation Greenhouse Gas Reduction Fund (GGRF) Investments Grant Program. Project partners include CARB, SCAQMD, BAAQMD, CTE, New Flyer and Ballard Power Systems. SCAQMD provided $1 million in cost-share to develop and demonstrate 10 zero emission fuel cell transit buses for the Orange County Transportation Authority (OCTA). As a part of this project, Trillium CNG working with Air Products and Chemicals Inc. will also construct and maintain a hydrogen refueling station. The fuel cell buses will be on a New Flyer Xcelsior® XHE40 platform with a Ballard Power Systems fuel cell. CTE anticipates that these fuel cell buses will be in service at the transit agencies by December 2018. Ten fuel cell buses and an upgraded hydrogen refueling station will also be demonstrated at AC Transit in Northern California. The New Flyer 40-foot transit bus will be assigned to five OCTA routes serving disadvantaged communities near its bus depot in Santa Ana. These routes are shown in Figure 10.

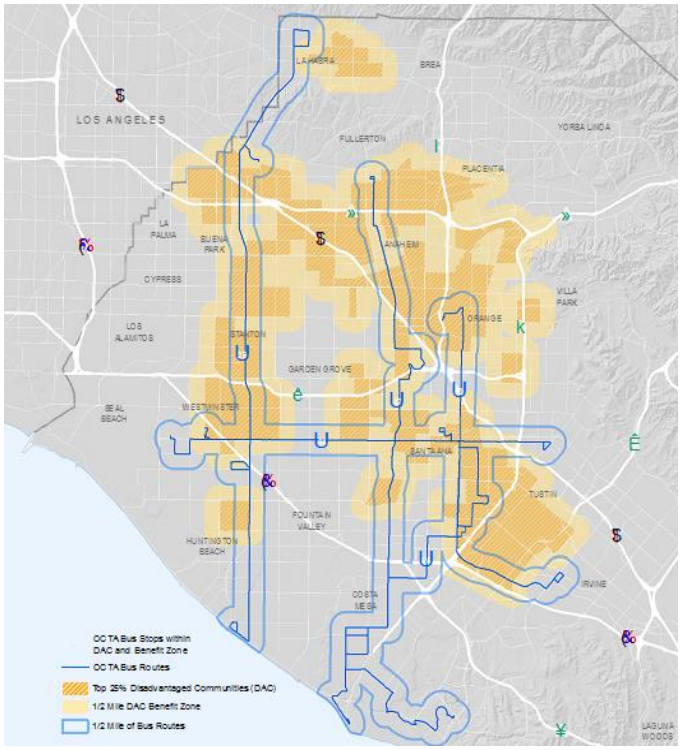


Figure 10: OCTA Routes in Disadvantaged Communities

The New Flyer 40-foot XHE 40 platform builds upon a weight reduced Xcelsior® platform, with more than 6,000 buses sold in 35-foot, 40-foot and 60-foot versions. This ensures that transit agencies can count on reliability and expect a 12-year, 500,000-mile equipment life typical for an urban transit bus.

New Flyer will be the primary integrator of battery electric and fuel cell technology, utilizing a combination of batteries, fuel cell and hydrogen storage. The electric drive system enables the fuel cell to operate at a relative steady state, while the batteries will feature regenerative breaking and power for acceleration. Technology advancements for this version of the New Flyer fuel cell transit bus include a Siemens modular electric hybrid traction system with the highest degree of flexibility, inverters and system controls which has been deployed on over 3,000 vehicles worldwide, and an efficient permanent magnet electric traction motor that has been deployed since 2008. For the battery pack, New Flyer customizes its own 80 kWh lithium-iron-phosphate battery pack with a proprietary liquid cooled system to maintain ideal battery temperatures. The battery electric version of the New Flyer XHE 40 bus passed all Federal Transit Administration's Altoona testing, designed to ensure better reliability and in-service performance of transit buses by providing an unbiased and accurate comparison of bus models through the use of an established set of test procedures.

Figure 11: New Flyer Xcelsior® XHE 40 Bus

New Flyer will be partnering with Ballard Fuel Cells to integrate Ballard's proton exchange membrane (PEM) fuel cell technology into the XHE 40 bus to incorporate a commercially available Ballard FCveloCity® HD 85 kW fuel cell, which has a proven durability of over 20,000 hours of operation in the field without failure. Hydrogen storage will be roof-mounted as on the CNG fueled Xcelsior® XN40 model with 38 kg of hydrogen fuel tanks at 350 bar pressure. The hydrogen storage system is compatible with fast-fill requirements using SAE's J2601-2 and J2578 fueling and safety protocols. The bus is expected to have a range of up to 300 miles. The features of New Flyer's XHE 40 fuel cell transit bus are shown below in Figure 12.

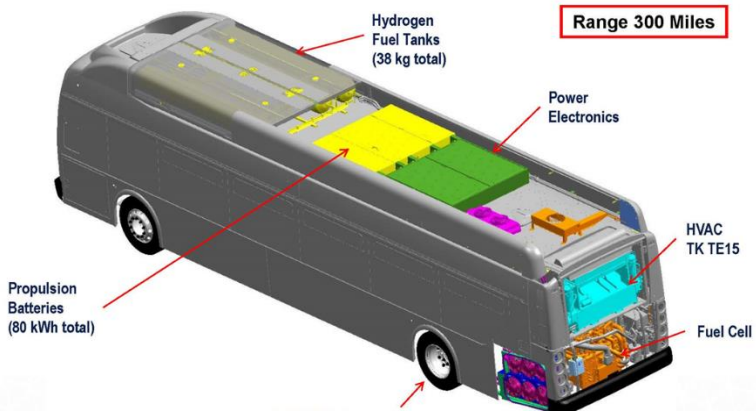


Figure 12: Features of Fuel Cell Transit Bus

Technical specifications, Altoona testing and integration of battery and fuel cell components will occur in 2018. It is anticipated that fuel cell bus deliveries to the transit agencies will be initiated by December 2018, with staggered deployment occurring through 2020; data collection activities and final reporting will be completed by spring 2020.

In November 2017, OCTA approved the execution of a contract with Trillium CNG, Inc., to construct a new hydrogen fueling station at OCTA's headquarters. This will be a fast-fill hydrogen station with 310 kg of high pressure storage capacity at 450 bar, capable of over six back-to-back fills per hour and an average fill time of six minutes.

Figure 13: Transit Bus Hydrogen Fueling Station

In preparation for construction of the new hydrogen fueling station, the OCTA site will have electrical, water, communication, ventilation and gas detection system upgrades. It is anticipated that OCTA's new hydrogen fueling station should be operational by the end of 2018, in time for the first two fuel cell buses to be delivered to OCTA for the beginning of the one year demonstration period. This project will leverage past efforts by AC Transit to demonstrate fuel cell transit buses and infrastructure and OCTA's first demonstration of fuel cell transit buses and infrastructure.

Development of Retrofit Technology for Natural Gas Engines and In-Use Emissions Testing of On-Road Heavy-Duty Trucks

On-road heavy-duty engines are now subject to the 2010 U.S. EPA emissions standards of 0.2 g/bhp-hr NOx and 0.01 g/bhp-hr PM. However, engine manufacturers are still using emission credits which allow them to produce a mixture of engines certified at or below the 2010 NOx emission standard of 0.2 g/bhp-hr NOx and engines certified at a level higher than 0.2 g NOx to comply with emission standards on an average basis. While recent studies have shown NOx and PM emissions are reduced from heavy-duty vehicles powered by modern technology engines, emissions from heavy-duty vehicles still dominate the total basin-wide NOx and PM emissions. In addition, a new heavy-duty natural gas

engines recently certified by CARB achieves a 90% lower NOx emissions level than the current 2010 engine emission standard. Therefore, additional assessment of in-use vehicle emissions remains a critical component for measuring the effectiveness of engine, fuel and aftertreatment technologies and improving emission inventories for air quality modeling and planning as well as developing effective strategies toward achieving the federal ambient air quality standards.

In 2016, the SCAQMD decided to conduct in-use emissions testing, including fuel usage profile characterization as well as an assessment of the impact of current technology and alternative fuels on fuel consumption. The in-use emissions testing would be conducted on heavy-duty vehicles with a gross weight rating greater than 14,000 pounds. The project was designed to involve up to 200 on-road heavy-duty vehicles used in transit, school bus, refuse, delivery and goods movement applications and powered by engines fueled with alternative fuels, conventional and alternative diesel fuels, and a combination of diesel and natural gas (dual) fuels. The engines will be categorized into six groups including natural gas engines certified at or below 0.2 g/bhp-hr NOx, engines certified at or below 0.02 g/bhp-hr NOx, diesel engines certified at or below 0.2 g/bhp-hr NOx, diesel engines without selective catalytic reduction, dual fuel engines and alternative fuel engines (hybrid and fully electric technology). Because of the complexity and breadth of the project, two contractors will complete the project, ensuring reliability and quality assurance of the test results.

Figure 14: Examples of Test Vehicles

West Virginia University (WVU) and the University of California Riverside/College of Engineering-Center for Environmental Research & Technology (UCR/CE-CERT) will be required to instrument test vehicles with portable emissions measurement systems (PEMS), portable vehicle activity measurement systems (PAMS), and other hardware to monitor daily vehicle activities, fuel usage profile and emissions. Both contractors will then use the PEMS' and PAMS' results to recommend whether to develop new and improved or retain existing vocation-based heavy-duty drive cycles.

In addition, they will be required to: 1) perform chassis dynamometer tests of a number of selected test vehicles, 2) instrument a number of test vehicles used in delivery and good movement applications with laboratory-grade test equipment to assess real-world in-use emissions, fuel usage profile and engine aftertreatment technology performance as the vehicles are driven over typical vocation routes, 3) match vehicle technologies to vocations for which technology benefits can be maximized, and 4) provide recommendations on how to prioritize staff and financial resources to support advanced engine and aftertreatment technology research and demonstration programs.

Figure 15: Sample PAMS

Figure 16: Sample PEMS

Emissions analysis will include total hydrocarbon, methane and non-methane hydrocarbon, nitrogen monoxide, nitrous oxide, nitrogen dioxide, carbon monoxide, carbon dioxide, ammonia, particulate matter, and ultrafine emissions at engine-out, tailpipe, and pre and post aftertreatment devices. Additionally, emissions of benzene, toluene, ethylbenzene, xylene, formaldehyde, acetaldehyde, and carbonyl will be assessed. Complementary to the in-use emissions study, UCR/CE-CERT will investigate the physical and chemical composition of secondary organic aerosol formation formed by the reaction of gaseous and particulate emissions from two natural and two diesel heavy-duty vehicles. The in-use emissions study will be used to measure the effectiveness of engine, fuel, and aftertreatment technologies, improve emission inventories for air quality modeling and planning, and match vehicle technologies to vocations for which technology benefits can be maximized as well as develop effective strategies toward achieving the federal ambient air quality standards. The result of the SOA study will provide valuable information on primary and secondary particulate emissions including SOA from in-use heavy-duty diesel and natural gas vehicles and facilitate a discussion on potential mitigation strategies.

Figure 17: Chassis Dynamometers at UCR and WVU

Technology Deployment and Commercialization

One function of the Clean Fuels Program is to help expedite the deployment and commercialization of low and zero 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 SCAQMD's Technology Advancement Office (TAO) administers not only the Clean Fuels Program but also the Carl Moyer Program. While the Clean Fuels Program will mark its 30th year in 2018, so too does the Carl Moyer Program[5] achieve a hallmark in 2018. Specifically, it is the 20th year of the Carl Moyer Program. These two programs produce a unique synergy, with the Carl Moyer Program providing the necessary incentives to push market penetration of the technologies developed and demonstrated by the Clean Fuels Program. This synergy enables the SCAQMD through its Clean Fuels Program, coupled with Carl Moyer and other incentive programs TAO oversees, to act as a leader in both technology development and commercialization efforts targeting reduction of criteria pollutants.

This report, however, is required to detail the accomplishments and achievements of the Clean Fuels Program. Therefore, the following projects contracted during CY 2017 illustrate the impact of the SCAQMD's technology deployment and commercialization efforts under the Clean Fuels Program and include: (a) Production and Commercialization of CNG Engines Certified at 0.02 NOx g/bhp-hr; (b) Development, Demonstration and Commercialization of Vehicle-to-Grid Electric School Buses; and

[5]For more information about the Carl Moyer Program and other SCAQMD incentive programs, visit this link: http://www.aqmd.gov/home/programs/business/business-detail?title=heavy-duty-engines&parent=vehicle-engine-upgrades

(c) he California Fuel Cell Partnership and Strides in Fuel Cell Vehicles and Hydrogen Infrastructure.

Production and Commercialization of CNG Engines Certified at 0.02 NOx g/bhp-hr

The development of CNG engines certified 90% below the existing CARB heavy-duty engine NOx standard, under the optional low-NOx standard, has led to successful development, production and commercialization of two CNG engines - an 8.9L and an 11.9L. These commercialized near-zero CNG engines provide additional and vital support towards California's efforts on lowering heavy-duty engine standards, as well as the SCAQMD's petition to the U.S. EPA for a similar national standard.

Cummins Westport, Inc. (CWI), using cost-sharing from SCAQMD, the California Energy Commission, Clean Energy and the Southern California Gas Company, was able to obtain CARB and U.S. EPA certification for both engines at 0.02 g/ bhp-hr for NOx. The intended pathway to commercialization was successful and both engines are now in production. More than a million miles of successful demonstration proved the engines are ready for commercialization, with the 8.9L engine in refuse and other vocational trucks as well as transit and school buses, and the 11.9L in Class 8 drayage trucks and 60-foot articulated transit buses.

Figure 18: CWI's 8.9L Engine

The 11.9L commercialization path is even more significant, since it provides an important alternative to diesel engines, especially for near-term 90% reduction in NOx emissions; and incentive funds, combined with the Clean Air Action Plan adopted by local ports and California's Sustainable Freight Action Plan, are anticipated to accelerate the fleet turnover for drayage trucks. Of the 260,000 diesel trucks operating throughout the South Coast region, approximately 10,000 are drayage trucks operating in and around the Ports. The use of RNG, combined with

The 8.9L has been offered in bus applications and refuse trucks throughout the region and has been eligible for incentive funding, including SCAQMD's Carl Moyer Program, with significant market penetration in the SCAQMD. The use of renewable natural gas (RNG) in the 8.9L engine, considering the funding available through the Low Carbon Fuel Standard Program and shared by the suppliers with the end users, has been a cost-effective option for local transit authorities to reduce criteria pollutant emissions and achieve the GHG reduction goals.

Figure 19: CWI's 11.9L Engine

the 11.9L near-zero emission engine in the drayage truck market is anticipated to be a more cost-effective pathway in the near-term to achieve significant NOx and GHG reduction goals included in the 2016 Air Quality Management Plan. Whilst other alternative technologies, including battery electric and fuel cells, have been announced by OEMS as viable alternatives to ICEs, significant implementation is not anticipated for the next ten years, mainly due to the greater incremental cost and lack of charging/refueling infrastructure.

Development, Demonstration and Commercialization of Vehicle-to-Grid Electric School Buses

The V2G Electric School Bus Demonstration Project was to demonstrate that vehicle-to-grid (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. In October 2013, the CEC awarded National Strategies, LLC (NSI), a $1,473,488 grant to develop and demonstrate six electric school buses with vehicle-to-grid and vehicle-to-building functionality (V2G/B) in school districts across California. School buses are ideal for V2G/B operation since they typically operate in the morning and afternoon for a few hours but remain parked most of the day. In this project, two of the zero emission school buses were demonstrated in the South Coast Air Basin with Torrance Unified School District (TUSD). The TUSD was awarded $456,552 by SCAQMD for two diesel school buses that were converted to electric buses with vehicle-to-grid (V2G) capability. National Strategies, LLC, was awarded $250,000 from the Clean Fuels Fund to develop and demonstrate V2G technology with TUSD. TUSD's contract closed in 2017, while the contract with NSI closes in 2018.

In collaboration with the V2G School Bus Management Team, comprising TransPower, University of Delaware, the National Renewable Energy Laboratory (NREL) and TUSD, the project has successfully demonstrated a path towards V2G capabilities using the stored battery energy of the TransPower electric school bus to safely and efficiently feed the test grid at NREL's Energy Systems Integration Facility. This project has laid the groundwork for follow on V2G capabilities of the electric school buses, as well as TransPower's entire product line. The project also supported SAE's J3072 (Interconnection Requirements for Onboard, Utility-Interactive Inverter Systems), as well as supported future industry standards for heavy-duty vehicle onboard high power charging systems. The resulting test data from this project has been shared with all our project partners, including Southern California Edison and will support the interconnection agreement at TUSD, enabling real-world demonstration of V2G capabilities and direct monetary benefits to V2G enabled school districts.

Figure 20: Electric School Bus with V2B and V2B Functionality

Because of the encouraging results of V2G Electric School Bus Demonstration, which is ongoing, SCAQMD decided to continue efforts to assist the commercialization of electric school buses and further the development of V2G technology. Blue Bird Body Company (Blue Bird) is one of the largest suppliers of school buses in the South Coast and has previously developed and commercialized alternative fuel buses. Blue Bird has been investigating methods of introducing electric vehicles into the national school bus market for the last decade. In 2010, Blue Bird hired consulting firm NSI to conduct an independent evaluation of market entry strategies. In 2015, Blue Bird reengaged with NSI and in parallel conducted its own independent evaluation of potential electric drivetrain suppliers. DOE recently awarded the Blue Bird Body Company a $4,902,237 grant to develop and demonstrate electric

school buses with V2G capability. SCAQMD is providing $1.9 million towards this follow-up effort.

A unifying, higher-level objective for Blue Bird's targeted technologies is to create a compelling value proposition for electric school buses, mainly by improving performance and efficiency, thereby reducing operating costs, and to create new opportunities for generating revenues through the export of battery power. This strategy led the Blue Bird Team to select three critical powertrain technologies for refinement: automated manual transmission (AMT), battery management system (BMS), and inverter-charger unit (ICU). The first critical success factor for achieving the project goal is leverage – leveraging Blue Bird's position as a leading bus OEM and its capabilities to put an electric bus through a complete OEM safety certification process for the first time; leveraging the millions of dollars their partners have invested and are continuing to invest in AMT technology to drive EVs to new levels of efficiency. Eventually, Blue Bird believes its V2G/V2B focus will leverage the interest of utilities in maintaining the efficiency and stability of the grid and society's need for portable energy sources to provide disaster resiliency, further enhancing the overall value of the project.

The current state of existing programs for full-size electric EV school buses is represented by a handful of vehicle models that have been introduced to the market over the last year. These buses have reported energy efficiency of 1.4 to 1.5 kWh per mile on a defined duty cycle, but most do not include V2G capability. At $325,000 for the entry-level model, the buses are about $215,000 more expensive than conventional California-ready diesel school buses.

Figure 21: Conventional California School Buses Ready For Electrification

The ultimate impacts from the proposed project will unfold at four levels. The first level of impact is the direct technical improvements to the AMT and BMS. The Blue Bird Team is targeting energy efficiency of 1.1 kWh per mile for an improvement around 20-30%. An efficiency gain of this magnitude will enable commensurate reductions in the amount of battery energy storage. Blue Bird expects that once the manufacturing innovations and economies of scale being pursued by the Blue Bird Team hit their stride, battery subsystem costs could be reduced by 50% or more versus the current state.

Figure 22: An Opportunity for Revenue in V2G Capabilities?

The second level of impact will be on the competitive economics of the EV school bus versus conventional diesel buses. The nature and importance of this impact will be documented in a market transformation study and analysis.

The third level of impact will be the displacement of diesel fuel. The national fleet of 500,000 school buses burns an estimated 750 million gallons of diesel fuel per year. Notably, this is 15-20% more than the national fleet of transit buses. Blue Bird believes that under the right circumstances, EV school buses will be taken up rapidly and help meet DOE's 2020 petroleum reduction goal, with growing impacts throughout the ensuing two decades. In addition, each EV bus will have a GHG footprint that is 70-80% smaller than a diesel bus, depending on the carbon intensity of local electricity generation.

The final level of impact will be the acceleration of the entrance of V2G technology into the commercial market. School buses represent an optimal use-case for V2G across all types of vehicles because of their significant energy storage capacity and usage patterns that allow them to be plugged in for 85% of the hours in a year. Once V2G technology and systems appropriate for heavy-duty fleets have been developed for school buses – and revenue benchmarks have been established (projected by the Blue Bird to be $4,000-$6,000 per year per vehicle) – a wide range of other medium- and heavy-duty fleet vehicles could be encouraged to follow the school buses' lead.

As a part of this effort, substantial work will be devoted to each of the three technical innovation modules listed above. All three components have been successfully developed through the proof-of-concept phase. The proposed project will focus on refining their configurations to production-ready designs and component certification and durability testing, including NREL export power testing and UL certification of the bi-directional inverter. Subsequently, the focus of effort shifts to powertrain integration. Blue Bird will build four electric school buses that will be subjected to usual safety and durability test program. This includes crash testing of one-to-two buses and durability testing of another. This will be followed by integration of eight additional buses to be deployed by the Rialto Unified School District (RUSD). The eight production buses, upon receipt of certification from the California Highway Patrol, will be placed into service with RUSD. The final task will be development of a Market Transformation Plan describing in detail how Blue Bird, with the assistance of its team members, will commercialize electric school buses using the demonstrated drive system.

In 2017, incentive funding available for electric school buses has initiated significant interest in this technology, with four OEMs registered under the Hybrid and Zero Emission Truck and Bus Voucher Incentive Project (HVIP) program, and SCAQMD has awarded numerous school districts funds towards this commercialization effort.

The California Fuel Cell Partnership and Strides in Fuel Cell Vehicles (FCVs) and Hydrogen Infrastructure

The California Fuel Cell Partnership (CaFCP) was initiated in 1999 with public and private entities as a means to accelerate response to CARB's ZEV regulations. Because of the alignment of CARB, SCAQMD and CaFCP goals for accelerated fuel cell vehicle commercialization, the SCAQMD Board accepted the CaFCP's formal invitation to join as a full member in March 2000.

Initially, the CaFCP focused on development of vehicles, infrastructure and outreach plans for future projects. Leveraging resources from members including vehicle OEMs, energy providers and government, CaFCP established a goal to accelerate and improve the commercialization process for all categories of vehicles: passenger, bus, truck, etc. The members have a shared vision, refined over time, 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. The CaFCP has been involved in the demonstration of cars and buses using gaseous and liquid hydrogen and methanol since its inception.

A CaFCP Fuel Scenarios Study resulted in the coordinated demonstration of fuel cell passenger vehicles, and then a limited number of fleet customer placements began in 2002. The CaFCP and

Figure 23: CaFCP Press Event at SCAQMD for Fuel Scenario Study (2001)

members demonstrated several generations of fuel cell cars and buses focused on using increasingly standardized gaseous hydrogen fuel at 350 bar and 700 bar pressures.

Next, several automakers started retail placement of fuel cell vehicles near hydrogen stations in early market communities. The CaFCP staff, with member support, developed a "Roadmap" for the introduction of fuel cell passenger vehicles with sufficient hydrogen fueling stations in California, followed by a "Bus Roadmap" and, most recently, a Medium- & Heavy-Duty Fuel Cell Electric Vehicle Action Plan. These roadmaps and other studies provided technical support for public funding of hydrogen fueling stations.

Figure 24: CaFCP Road Rally started by fueling at first SCAQMD Hydrogen Station (2004)

In January 2012, CARB approved advanced clean car regulations, which harmonized California requirements with federal requirements from 2017–2025 and incorporated GHG emission reductions. The SCAQMD's 2016 AQMP and Clean Fuels Program 2018 Plan Update identify fuel cells for on- and off-road applications as a core technology for attaining and maintaining cleaner air quality.

With the commitment of funding under AB 8 to develop and operate approximately 100 hydrogen retail fueling stations in California through 2023, and the collaboration of California with other states to support ZEVs, automakers are continuing to announce market launches. Some automakers are combining efforts to share intellectual property, build component supply chains and leverage resources - Daimler with Ford and Nissan, Toyota with BMW, and General Motors with Honda. Germany, Japan and South Korea have also committed funding to build more hydrogen stations, and international momentum is building with establishment of the Hydrogen Council in 2017. More recently, California Governor Jerry Brown issued an executive order (#B-48-18 issued 1/16/18) calling for increasing the deployment of zero emission vehicles and developing 200 hydrogen refueling stations.

Figure 25: CaFCP Hydrogen Quality Sampling Adapter

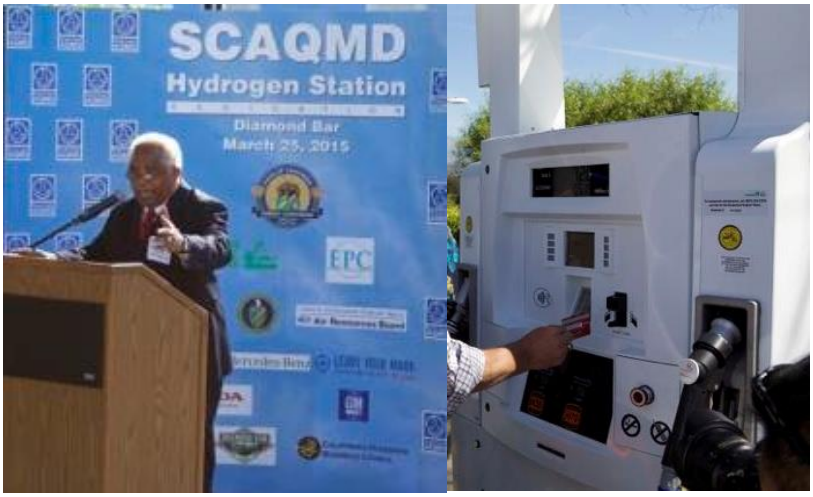
Figure 26: CaFCP Road Rally Visits Santa Monica Pier on the way from Chula Vista, CA, to Vancouver, B.C. (2009)

Figure 27: CaFCP Member SunLine Transit Provides Fuel Cell Bus Transportation for Fuel Cell Seminar (2009)

Figure 28: CaFCP & DOE Provide LA County Fire Dept. Emergency Responder Training (2012)

At the request of SCAQMD, the CaFCP expanded its presence in Southern California due to the increased deployment of vehicles, the largest number of fueling stations and the greatest air quality need in this region. A CaFCP Regional Coordinator based in the South Coast region supports member activities and outreach and an Infrastructure Specialist facilitates hydrogen station development.

Figure 29: SCAQMD Board Member Clark E. Parker, Sr., at SCAQMD Retail H2 Station Event (2015)



Major accomplishments for 2017 include:

- More than 3,000 consumers and fleets have purchased or leased passenger category FCEVs from Hyundai, Toyota and Honda since they entered the commercial market starting in 2015.
- Transit agency members have 20 fuel cell electric buses currently in operation and more than 30 additional funded and to be deployed. Now operating five fuel cell electric buses in regular service, SunLine Transit is planning to add 12 fuel cell transit buses and two shuttle buses by the end of 2018 and is upgrading its hydrogen station.
- There are 31 retail and four other non-retail hydrogen fueling stations in operation in California, with an additional 34 in development, with the majority in the Southern California area.
- CaFCP staff and members continue to conduct outreach and education in communities throughout California.
- CaFCP, the Governor's Office of Business and Economic Development (GO-Biz) and the California Energy Commission, continue advising and responding to city staff across the state of California to optimize station permitting.
- CaFCP created and maintains the Station Operational Status System (SOSS) that more than 30 hydrogen stations in the U.S. use to report status. This data, in turn, feeds real-time information (address, availability, etc.) to consumers through a CaFCP mobile-friendly website and several other apps and systems that support consumers.

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 effort. CaFCP members, individually or in groups, are focusing on the following important goals:

- 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 RDD&D projects.
- Continue research, development and demonstration of advanced concepts in renewable and other low-carbon hydrogen.
- Provide education and outreach to the public and community stakeholders on the role of FCEVs and hydrogen in the evolution to electric drive. With additional support from some CaFCP members to facilitate the foundational work required for the growth of medium- and heavy-duty fuel cell truck and bus deployments, additional tasks for fuel cell truck and bus codes and standards coordination are proposed for 2018:
- Sponsor revision of SAE J2600, Compressed Hydrogen Surface Vehicle Fueling Connection Devices, to include high flow interface geometries and align with ISO 17268.

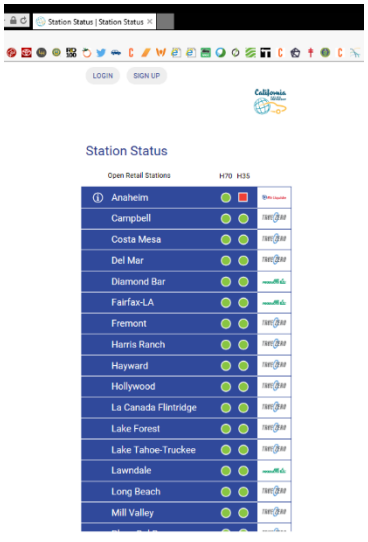


Figure 30: CaFCP SOSS

- Sponsor SAE J2601-2, Fueling Protocol for Gaseous Hydrogen Powered Heavy Duty Vehicles, from Technical Information Report (TIR 2014) to Surface Vehicle Standard & align with J2600 & ISO.
- Update general medium-duty/heavy-duty vehicle and infrastructure safety, codes and standards, and update first responder training.
- Facilitate task forces (truck and bus) and outreach and coordinate a 2018 Fuel Cell Electric Truck (FCET) Action Plan, building on the Project Portal demonstration by Toyota designed to support Class 8 port drayage operations at the Port of Los Angeles.

The next couple of years should continue to achieve huge strides in fuel cell vehicle technology and hydrogen infrastructure growth, supporting a variety of vehicles. SCAQMD plans to continue to be a leader in this core technology area.

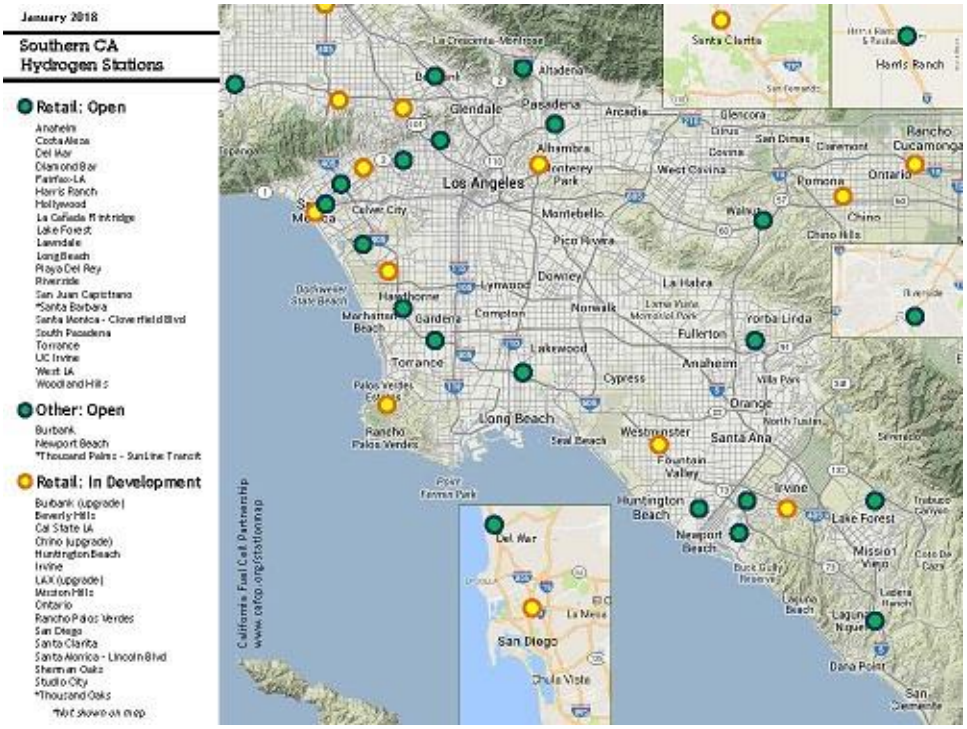


Figure 31: Southern California Hydrogen Stations (January 2018)

(Photo Credit: Photos and images above courtesy of CaFCP)

CLEAN FUELS PROGRAM
2017 Funding & Financial Summary

The SCAQMD 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 4), the SCAQMD 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 SCAQMD Governing Board.

As projects are approved by the SCAQMD 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, 2017.

Funding Commitments by Core Technologies

The SCAQMD 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, 2017, a total of 67 contracts, projects or studies that support clean fuels were executed or amended, as shown in Table 2 (page 36). 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 32 (page 34). This wide array of technology support represents the SCAQMD'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 2017 reporting period are shown below with the total projected project costs:

- SCAQMD Clean Fuels Fund Contribution $17,855,039
- Total Cost of Clean Fuels Projects $118,710,080

Traditionally every year, the SCAQMD Governing Board approves funds to be transferred to the General Fund Budget for Clean Fuels administration. For 2017, the fund transfer from Clean Fuels to the General Fund was handled through the annual budget process. Thus, when the Board approved the SCAQMD's FY 2017-18 Budget on June 2, 2017, it included $1 million from Clean Fuels recognized in TAO's budget for workshops, conferences, cosponsorships and outreach activities as well as postage, supplies and miscellaneous costs. Only the funds committed by December 31, 2017, are included within this report. Any portion of the Clean Fuels Funds not spent by the end of Fiscal Year 2017-18 ending June 30, 2018, will be returned to the Clean Fuels Fund.

Partially included within the SCAQMD contribution are supplemental sponsorship revenues from various organizations that support these technology advancement projects. This supplemental revenue for pass-through contracts executed in 2017 totaling $6.2 million is listed within Table 3 (page 39).

Appendix B lists the 94 Clean Fuels Fund contracts that were open and active as of January 1, 2018.

For Clean Fuels executed and amended contracts, projects and studies in 2017, the average SCAQMD contribution is approximately 16.5 percent of the total cost of the projects, identifying that

each dollar from the SCAQMD was leveraged with more than $6 of outside investment. The typical leverage amount is $3-$4 for every $1 of SCAQMD Clean Fuels funds, but both 2016 and 2017 notably had several significant contracts, significant both in funding and in the impact they hopefully will make in strides toward developing and commercializing clean transportation technologies.

During 2017, the distribution of funds for SCAQMD executed contracts, purchases and contract amendments with additional funding for the Clean Fuels Program totaling approximately $17.9 million are shown below in Figure 32.

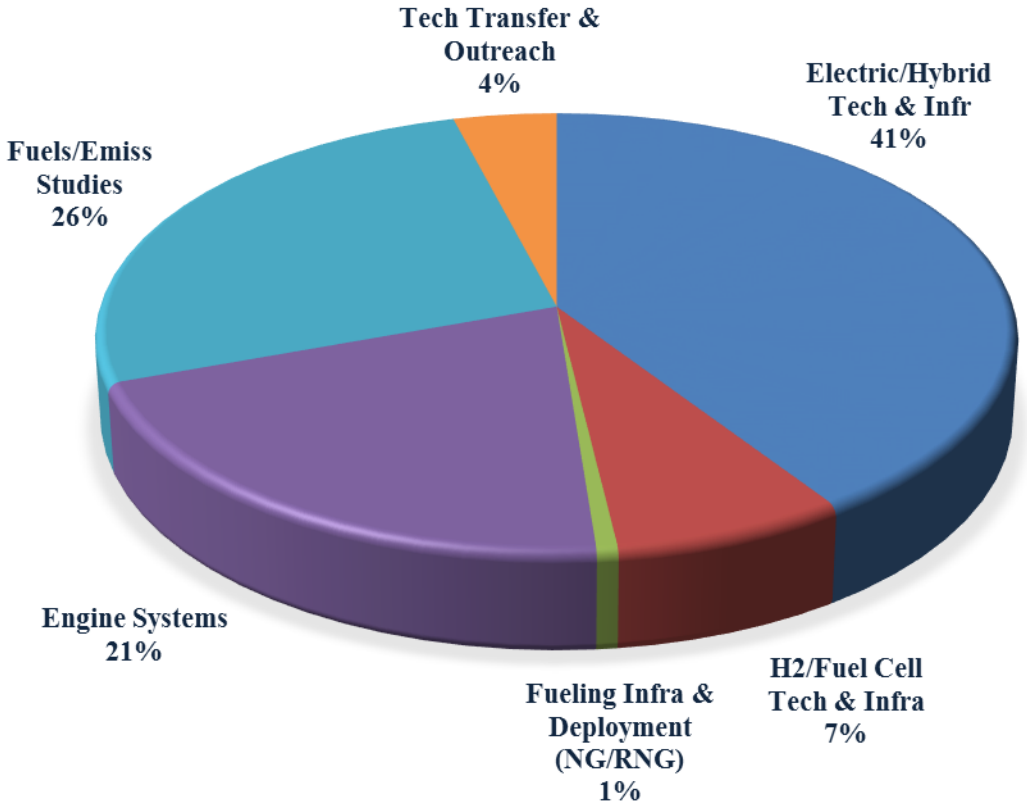


Figure 32: Distribution of Funds for Executed Clean Fuels Projects CY 2017 ($17.9M)

Table 2 (page 36) provides a breakdown of this $17.9 million in executed contracts.

Table 3 (page 39) provides information on outside funding recognized and received into the Clean Fuels Fund ($6.2 million) for contracts executed in CY 2017. Additionally, the SCAQMD continued to seek funding opportunities and

Table 4 (page 40) lists the additional $20.5 awarded in 2017 for projects that will be implemented as part of the Clean Fuels Program or which align well and complement the Clean Fuels Program but were recognized in another special revenue fund for fiduciary reasons.

Review of Audit Findings

State law requires an annual financial audit after the closing of each SCAQMD'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, 2017, 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 SCAQMD financial statements, which include the Clean Fuels Program revenue and expenditures.

BCA Watson Rice, LLP, gave the SCAQMD an "unmodified opinion," the highest obtainable. Notably, the SCAQMD has achieved this rating on all prior annual financial audits.

Project Funding Detail by Core Technologies

The 67 new and continuing contracts, projects and studies that received SCAQMD funding in 2017 are summarized in Table 2, together with the funding authorized by the SCAQMD and by the collaborating project partners.

Table 2: Contracts Executed or Amended (w/$) between Jan. 1 & Dec. 31, 2017

Contract	Contractor	Project Title	Start Term	End Term	SCAQMD $	Project Total $
Hydrogen/Mobile Fuel Cell Technologies and Infrastructure						
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
17394	Energy Independence Now	Provide Analysis of Renewable Hydrogen Pathways, Economics and Incentives	10/20/17	03/19/18	25,000	140,000
18118	Frontier Energy, Inc. (formerly BKi)	Participate in California Fuel Cell Partnership in CY 2017 and Provide Support for Regional Coordinator	01/01/17	12/31/17	120,000	1,520,000
Engine Systems/Technologies						
16205	Cummins Westport, Inc.	Develop, Integrate and Demonstrate Ultra-Low Emission 12L Natural Gas Engines for On-Road Heavy-Duty Vehicles	06/03/16	06/30/18	2,500,000	2,500,000
17197	VeRail Technologies Inc.	Develop and Demonstrate Ultra-Low Emission Natural Gas Switcher Locomotive	03/03/17	09/02/19	1,000,000	5,100,000
18018	North American Repower LLC	Develop High Efficiency Near-Zero Natural Gas Engines for Heavy-Duty Vehicles	12/14/17	12/12/19	200,000	1,958,096
Electric/Hybrid Technologies and Infrastructure						
15610	Goss Engineering, Inc.	Conduct Engineering Services at SCAQMD Headquarters	06/02/15	12/31/17	10,000	10,000
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
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

Table 2: Contracts Executed or Amended (w/$) between Jan. 1 & Dec. 31, 2017 (cont'd)

Contract	Contractor	Project Title	Start Term	End Term	SCAQMD $	Project Total $
Electric/Hybrid Technologies and Infrastructure (cont'd)						
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
Direct Pay	Clean Fuel Connection Inc.	Install Electric Vehicle Supply Equipment	01/03/17	08/15/17	20,614	20,614
Direct Pay	Various	Conduct Work for EVSE Upgrade at SCAQMD Headquarters	01/24/17	08/11/17	14,143	14,143
Direct Pay	Selman Chevrolet Company	Purchase One 2017 Chevrolet Volt EV for TAO's Fleet Demonstration Program	09/06/17	09/06/17	38,653	38,563
Fueling Infrastructure and Deployment (NG/RNG)						
15541	Foundation for California Community Colleges	Implement Enhanced Fleet Modernization Program	05/07/15	01/30/19	21,270	30,000
17349	University of California Riverside/CE-CERT	Establish Renewable Natural Gas Center	08/03/17	08/02/18	100,000	261,110
Fuels/Emissions Studies						
15680	National Renewable Energy Laboratory	ComZEV: Develop Detailed Technology and Economics-Based Assessment for Heavy-Duty Advanced Technology Development	08/25/15	06/30/18	20,000	40,000
17245	West Virginia University Research Corporation	Conduct In-Use Emissions Testing and Fuel Usage Profile of On-Road Heavy-Duty Vehicles	04/14/17	10/31/18	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	11/02/19	350,000	524,000

Table 2: Contracts Executed or Amended (w/$) between Jan. 1 & Dec. 31, 2017 (cont'd)

Contract	Contractor	Project Title	Start Term	End Term	SCAQMD $	Project Total $
Fuels/Emissions Studies (cont'd)						
17278	University of Southern California	Develop Freight Loading Strategies for Zero Emissions Heavy-Duty Trucks in Goods Movement	11/03/17	11/02/19	200,000	1,001,000
17286	University of California Riverside/CE-CERT	Conduct In-Use Emissions Testing and Fuel Usage Profile of On-Road Heavy-Duty Vehicles	06/09/17	06/08/21	1,625,000	1,625,000
17331	University of California Riverside/CE-CERT	Conduct In-Use PM Emissions Study for Gasoline Direct Injection Vehicles	07/14/17	07/31/18	222,000	273,000
17352	California State University Maritime Academy	Develop and Demonstrate Vessel Performance Management Software and Equipment	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	12/04/18	85,000	85,000
Technology Assessment/Transfer and Outreach						
17037	Clean Fuel Connection Inc.	Technical Assistance with Alternative Fuels, Electric Vehicles, Charging and Fueling Infrastructure and Renewable Energy	11/18/16	11/17/18	50,000	50,000
17097	Gladstein, Neandross & Associates LLC	Technical Assistance with Alternative Fuels and Fueling Infrastructure, Emissions Analysis and On-Road Sources	11/04/16	11/03/18	100,000	100,000
17336	Three Squares Inc.	Conduct Education Outreach for the Basin DC Fast Charging Network Project	05/12/17	06/30/18	64,183	64,183
17358	AEE Solutions, LLC	Technical Assistance with Heavy-Duty Vehicle Emissions Testing, Analysis and Engine Development	06/09/17	09/08/19	100,000	100,000
18019	Ricardo Inc.	Technical Assistance with Heavy-Duty Vehicle Emissions Testing, Analysis, and Engine Development and Applications	09/01/17	08/31/19	50,000	50,000
Direct Pay	Hartford/Alliant Insurance	Insurance for Alternative Fuel Vehicles in TAO's Fleet Demonstration Program	01/01/17	12/31/17	40,000	40,000
Direct Pay	Various	Cosponsor 22 Conferences, Workshops & Events plus 5 Memberships	01/01/17	12/31/17	324,804	4,456,755
		GRANDTOTAL – ALL CORE TECHNOLOGIES			**$17,855,039**	**$118,710,080**

Table 3: Supplemental Grants/Revenue Received into the Clean Fuels Fund (31) in CY 2017

Revenue Agreement #	Revenue Source	Project Title	Contractor	SCAQMD Contract #	Award Total $
15022 Mod2	California Energy Commission	Develop, Integrate and Demonstrate Ultra-Low Emission 12L Natural Gas Engines for On-Road Heavy-Duty Vehicles	Cummins Westport Inc.	16205	1,000,000
17039	Clean Energy	Develop, Integrate and Demonstrate Ultra-Low Emission 12L Natural Gas Engines for On-Road Heavy-Duty Vehicles	Cummins Westport Inc.	16205	500,000
17096	California Energy Commission	Develop, Integrate and Demonstrate Ultra-Low Emission 12L Natural Gas Engines for On-Road Heavy-Duty Vehicles	Cummins Westport Inc.	16205	1,000,000
16220	California Energy Commission	On-Road In-Use Emissions Testing and (Fuel) Usage	University of California Riverside/ West Virginia University	17286/ 17245	2,000,000
17209	California Air Resources Board	On-Road In-Use Emissions Testing and (Fuel) Usage	University of California Riverside/ West Virginia University	17286/ 17245	150,000
17281	Southern California Gas Company	On-Road In-Use Emissions Testing and (Fuel) Usage	University of California Riverside/ West Virginia University	17286/ 17245	500,000
17038	Southern California Gas Company	Develop and Demonstrate Ultra-Low Emission Natural Gas Switcher Locomotive	VeRail Technologies, Inc.	17197	500,000
17055	U.S. Environmental Protection Agency	Develop and Demonstrate Ultra-Low Emission Natural Gas Switcher Locomotive	VeRail Technologies, Inc.	17197	500,000
Transfer	BP ARCO Settlement Fund 46	Design and Demonstrate Vessel Performance Management Software and Equipment	Cal State University Maritime Academy	17352	50,086
Table 3 lists revenue recognized by SCAQMD into the Clean Fuels Fund (31) only if the pass-through contract was executed during the reporting CY (2017).					**$6,200,086**

Table 4: Summary of Federal, State and Local Funding Awarded or Recognized in CY 2017

Awarding Entity or Program	Award or Board Date	Purpose	Contractors	Award Total $/Fund
CARB	02/03/17	FY 2016-17 Implementation of the Retire and Replace Component of Enhanced Fleet Modernization Program (EFMP) Plus-Up	Various	$5,000,000 Fund 56
Port of Los Angeles	10/31/17	Develop Ultra-Low Emission Diesel Engine for On-Road Heavy-Duty Vehicles	Southwest Research Institute	$287,500 Fund 31
2016 U.S. EPA Targeted Air Shed Grant	03/15/17	Commercial Electric Lawn and Garden Equipment Package Program	TBD	$2,477,250 Fund 17
BNSF	03/03/17	Install Air Filtration systems at Schools	IQAir North America	$625,000 Fund 75
Southern California Gas Company	02/07/17	Conduct RNG Commercial Field Test Project	KORE Infrastructure, Inc.	$1,000,000 Fund 76
California Energy Commission	02/22/17	Demonstrate Zero and Near-Zero Emission Drayage Trucks and Cargo Handling Equipment	Clean Energy/ Hyster-Yale Nederland BV/ Velocity Vehicle Group	8,395,000 Fund 31
U.S. EPA/ CATI	7/27/17	Develop Ultra-Low NOx Aftertreatment System for Large Displacement Engines	Southwest Research Institute/Rail Propulsion Systems	500,000 Fund 31
Port of Long Beach	07/07/17	Develop and Demonstrate Zero Emission Drayage Trucks	Hydrogenics USA Inc.	157,500 Fund 61
SSA Terminals	07/07/17	Install Air Filtration Systems at Schools	IQ Air North America	1,250,000 Fund 75
Wal-Mart Transportation, LLC/ Murillo's Trucking	10/06/17	Install and Maintain Air Filtration Systems at Schools	IQ Air North America	327,000 Fund 75
Ports of Los Angeles and Long Beach	10/06/17	Electric Yard Tractor Replacements at San Pedro Bay Ports	West Basin Container Terminal/Total Terminals International	500,000 Fund 17
U.S. EPA/ FY 2017 DERA	09/27/17	On-Road Heavy-Duty Diesel Drayage Truck Replacement Projects	Puget Sound Clean Air Agency/Others (TBD)	1,050,00 Fund 17
Table 4 provides a comprehensive summary of revenue awarded to SCAQMD during the reporting CY (2017) if it will be considered part of, or complementary to, the Clean Fuels Program, regardless of whether the pass-through contract has been executed.				**$20,519,250**

Project Summaries by Core Technologies

The following represents summaries of the contracts, projects and studies executed, or amended with additional dollars, in CY 2017. 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; SCAQMD cost-share, cosponsors and their respective contributions; contract term; and a description of the project.

Hydrogen/Mobile Fuel Cell Technologies and Infrastructure

17312: ZECT II: Develop Fuel Cell Range-Extended Drayage Truck

Contractor: Hydrogenics USA Inc.	SCAQMD Cost-Share	$ 125,995
	Cosponsors	
	Department of Energy *(received as pass-through funds into Fund 61)*	825,784
	California Energy Commission *(received as pass-through funds into Fund 61)*	983,858
	Port of Long Beach *(received as pass-through funds into Fund 61)*	157,500
	Hydrogenics USA Inc. (in-kind)	340,416
Term: 11/20/17 – 05/19/21	Total Cost:	$ 2,433,553

Hydrogenics USA Inc. and their OEM partners propose to build and demonstrate a fuel cell range extended Class 8 truck for the DOE Zero Emission Cargo Transport (ZECT) project. The drayage truck will be identical to the CEC drayage truck that Hydrogenics is currently designing under a CEC funded project. The truck design and development effort is fully funded under the CEC truck project, the electric drive system design of the truck will be duplicated for the ZECT Project. The fuel cell drayage truck will be demonstrated for 24 months in the Ports of LA and Ports of Long Beach. Hydrogenics will provide necessary support throughout the demonstration period, quarterly performance reports to SCAQMD, and one final report at the end of the project. The project is expected to be three years in duration, including one year of truck production and two years of demonstration.

17316: Develop and Demonstrate Ten Zero Emission Fuel Cell Electric Buses

Contractor: Center for Transportation and the Environment	SCAQMD Cost-Share	$ 1,000,000
	Cosponsors	
	California Air Resources Board	22,347,502
	Orange County Transportation Authority	9,334,772
	AC Transit	8,710,000
	Other Partners & In-Kind	2,936,585

	Bay Area Air Quality Management District	1,000,000
Term: 06/09/17 – 04/30/20	Total Cost:	$ 45,328,859

As part of a $45 million project and a $22 million CARB grant to Center for Transportation and the Environment (CTE), SCAQMD provided $1 million in cost-share to develop and demonstrate 10 zero emission fuel cell transit buses and a hydrogen fueling station at Orange County Transportation Authority. These fuel cell buses will be on a New Flyer platform with a Ballard Power Systems fuel cell. CTE anticipates that these fuel cell buses will be in service at the transit agencies by December 2018. Ten fuel cell buses and a hydrogen fueling station will also be demonstrated at AC Transit in a similar demonstration in Northern California.

17317: Three Year Lease of One Honda 2017 Clarity Fuel Cell Vehicle for TAO's Fleet Demonstration Program

Contractor: American Honda Motor Company, Inc.	SCAQMD Cost-Share	$ 17,304
Term: 03/22/17 – 03/21/20	Total Cost:	$ 17,304

SCAQMD has been working with American Honda and has participated in on-road testing of their fuel cell electric vehicles starting with research programs since 2004 when SCAQMD's first hydrogen station in Diamond Bar started fueling the first fuel cell car – the Honda FCX - in our fleet. Several fuel cell vehicle generations have resulted in the 2017 Honda Clarity Fuel Cell for retail lease through 12 specially trained dealerships near retail hydrogen fueling stations in California. The Honda Clarity fuel cell vehicle is a five-passenger sedan that travels 366 miles before refueling with 70 MPa gaseous hydrogen and has U.S. EPA estimated fuel economy of 67 mpge. The vehicle will be placed into SCAQMD's alternative fuel vehicle fleet to demonstrate new fuel cell vehicles to public and private organizations to promote zero emission technologies.

17343: Three Year Lease of One Honda 2017 Clarity Fuel Cell Vehicle for TAO's Fleet Demonstration Program

Contractor: American Honda Motor Company, Inc.	SCAQMD Cost-Share	$ 17,328
Term: 02/21/17 – 02/20/20	Total Cost:	$ 17,328

As noted, SCAQMD has been working with American Honda and has participated in on-road testing of their fuel cell electric vehicles starting with research programs since 2004 when SCAQMD's first hydrogen station in Diamond Bar started fueling the first fuel cell car – the Honda FCX - in our fleet. Several fuel cell vehicle generations have resulted in the 2017 Honda Clarity Fuel Cell for retail lease through 12 specially trained dealerships near retail hydrogen fueling stations in California. This second vehicle will also be placed into SCAQMD's alternative fuel vehicle fleet to demonstrate new fuel cell vehicles to public and private organizations to promote zero emission technologies.

17385: Three Year Lease of One Honda 2017 Clarity Fuel Cell Vehicle for TAO's Fleet Demonstration Program

Contractor: American Honda Motor Company, Inc.	SCAQMD Cost-Share	$ 17,304
Term: 05/17/17 – 05/16/20	Total Cost:	$ 17,304

This third Honda 2017 Clarity Fuel Cell will also be placed into SCAQMD's alternative fuel vehicle fleet to demonstrate new fuel cell vehicles to public and private organizations to promote zero emission technologies. Given the number of events the SCAQMD cosponsors and attends throughout the South Coast Air Basin, three of these vehicles were added to the Fleet Demonstration Program in 2017.

17394: Provide Analysis of Renewable Hydrogen Pathways, Economics and Incentives

Contractor: Energy Independence Now	SCAQMD Cost-Share	$ 25,000
	Cosponsors	
	Automakers: American Honda Motor Company, Toyota Motor Corporation	50,000
	Fuel Providers: Southern California Gas Company, Linde, Air Liquid and Hydrogenics USA Inc.	65,000
Term: 10/20/17 – 03/19/18	Total Cost:	$ 140,000

Energy Independence Now (EIN) will perform an analysis of renewable hydrogen pathways, economics and incentives. EIN will also develop a white paper and presentation to engage the broader stakeholder community to support renewable hydrogen education and outreach. This project will be cost-shared by automakers and fuel providers.

18118: Participate in California Fuel Cell Partnership in CY 2017 and Provide Support for Regional Coordinator

Contractor: Frontier Energy, Inc. (formerly BKi)	SCAQMD Cost-Share	$ 120,000
	Cosponsors	
	7 automakers, 6 public agencies, 2 industry stakeholders, 28 Full & Associate Members	1,400,000
Term: 01/01/17 – 12/31/17	Total Cost:	$ 1,520,000

In April 1999, the California Fuel Cell Partnership (CaFCP) was formed with eight members; SCAQMD joined and has participated since 2000. The CaFCP and its members are demonstrating and deploying fuel cell passenger cars and transit buses 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 2017, SCAQMD contributed $70,000 for Executive membership and up to $50,000, along with four cubicles at SCAQMD Headquarters, to provide support for the CaFCP Regional Coordinator.

Engine Systems/Technologies

16205: Develop, Integrate and Demonstrate Ultra-Low Emission 12L Natural Gas Engines for On-Road Heavy-Duty Vehicles

Contractor: Cummins Westport, Inc.	SCAQMD Cost-Share *(all received as pass-through funds)*	$ 2,500,000
Term: 06/03/16 – 06/30/18	Total Cost:	$ 2,500,000

This contract was amended to add cost-share from two project partners, specifically $2,000,000 from the California Energy Commission and $500,000 from Clean Energy, which had been recognized into the Clean Fuels Fund (31). The objective of this project is to apply the ultra-low emission engine and after-treatment technologies developed for an 8.9-liter ISL-G Z engine to the 11.9-liter ISX12-G Cummins Westport engine. The project includes 1) engine and after-treatment system design, development, and emission testing; 2) integration of the engine and after-treatment system into multiple vehicle chassis; and 3) on-road demonstrations including chassis dynamometer testing. Development targets are 1) power and torque suitable for heavy-heavy duty Class 8 vehicles; 2) a technology pathway to commercial production3) certification to the CARB Optional NOx standard of 0.02 g/bhp-hr, and 4) ammonia emissions and fuel economy penalties as low as possible. Development of ultra-low emission engines that emit 90% lower NOx than the 2010 0.2 g/bhp-hr NOx standard would significantly reduce their emissions and assist the region in meeting federal ambient air quality standards in future years. The Cummins Westport ISL-G NZ 8.9-liter natural gas engines, developed with the funding from the SCAQMD, the California Energy Commission and Southern California Gas Company, was certified by CARB to the Optional 0.02 g/bhp-hr NOx standard and is now being commercially used in refuse trucks and buses. However, the 8.9-liter engine is too small for heavy-heavy duty vehicles in Class 8, which requires development of larger displacement engines such as this 12L engine.

17197: Develop and Demonstrate Ultra-Low Emission Natural Gas Switcher Locomotive

Contractor: VeRail Technologies Inc.	SCAQMD Cost-Share *(all received as pass-through funds)*	$ 1,000,000
	Cosponsors	
	Port of Long Beach	300,000
	Port of Los Angeles	300,000
	VeRail Technologies Inc.	3,100,000
	PHL (in-kind)	400,000
Term: 03/03/17 – 09/02/19	Total Cost:	$ 5,100,000

This project will develop and demonstrate a 2,100 horsepower CNG-powered locomotive capable of operation in the San Pedro Bay Ports while producing near-zero emissions. CARB Tier 4 locomotive standards require a reduction in in NOx and PM by 70 %. The VeRail engine is expected to be 90% below current and with a 23% reduction in GHG. The project is expected to take place over two years with the objective of achieving a commercial ready product which can replace all 25 locomotives eventually in the Ports of Los Angeles and Long Beach. The goal is to develop an engine capable of operating at the San Pedro Bay Ports required duty cycle and certified at the CARB low NOx standard of 0.02 g/bhp-hr. The engine must also be fuel efficient and only be re-fueled once per week. The U.S. EPA and the Southern California Gas Company each provided $500,000 as pass-through funding, recognized into the Clean Fuels Fund (31), for this project.

18018: Develop High Efficiency Near-Zero Emission Natural Gas Engines for Heavy-Duty Vehicles

Contractor: North American Repower LLC	SCAQMD Cost-Share	$ 200,000
	Cosponsors	
	California Energy Commission	900,000
	Southern California Gas Company	150,000
	North American Repower LLC (in kind)	708,096
Term: 12/14/17 – 12/12/19	Total Cost:	$ 1,958,096

North American Repower LLC converts engines to CNG power for class 5-8 vehicles. The demand for more power and higher efficiency from CNG engines has led to a developmental project sponsored by the California Energy Commission and Southern California Gas Company. The objectives are to use a commercially available 13-liter diesel engine and convert it to CNG. The requirements will be to create more power and efficiency while achieving near-zero emissions. The engine is scheduled for production readiness in 2019.

Electric/Hybrid Technologies and Infrastructure

15610: Conduct Engineering Services at SCAQMD Headquarters

Contractor: Goss Engineering, Inc.	SCAQMD Cost-Share	$ 10,000
Term: 06/02/2015 – 12/31/17	Total Cost:	$ 10,000

In June 2015, SCAQMD executed a contract with Goss Engineering Services in the amount of $50,000 in response to RFP #P2015-21 to perform all necessary engineering services for the upgrade and expansion of SCAQMD's electric vehicle charging (EVC) infrastructure, to develop plans and diagrams for the installation of a separate electric utility line, transformer and meter for the CNG station, and to prepare as-built drawings. Due to the numerous pieces involved with the upgrade and expansion of SCAQMD's EVC infrastructure and electric demands, this contract was amended to add an additional $10,000. These additional funds were added to cover unanticipated site plan and permitting expenses. Specifically, permitting requirements which were not anticipated included a site survey to address American with Disabilities Act requirements and a short circuit study to address National Electrical Code requirements.

17029: Demonstrate and Evaluate Plug-In Smart Charging at Multiple Electric Grid Scales

Contractor: University of California Irvine	SCAQMD Cost-Share	$ 250,000
	Cosponsors	
	Department of Energy	100,000
	Southern California Edison	100,000
	Hyundai (in-kind)	300,000
Term: 06/29/17 – 06/28/20	Total Cost:	$ 750,000

The University of California Irvine's Advanced Power and Energy Program will develop and demonstrate a software algorithm for coordinating the charging of plug-in electric vehicles (PEVs) to support grid resource operation without compromising the ability of PEV drivers to meet their transportation needs. This project will simulate the deployment of the PEV Smart Charging algorithm at two different grid scales using ten Kia Soul EVs with smart charging capability.

17105: Develop and Demonstrate Up to 25 Class 8 Battery Electric Drayage Trucks

Contractor: BYD Motors Inc.	SCAQMD Cost-Share	$ 794,436
	Cosponsors	
	California Air Resources Board *(received as pass-through funds into Fund 67)*	5,657,564
	Bay Area Air Quality Management District *(received as pass-through funds into Fund 67)*	1,200,000
	San Joaquin Air Pollution Control District *(received as pass-through funds into Fund 67)*	100,000
	San Diego Air Pollution Control District/San Diego Gas & Electric *(received as pass-through funds into Fund 67)*	200,000
	BYD Motors Inc.	990,400
Term: 04/14/17 – 10/13/23	Total Cost:	$ 8,942,400

BYD will be developing a 100% battery-electric drayage truck that is optimized to serve near-dock and short regional drayage routes. BYD is a global company with over $9 billion in revenue and 180,000 employees, including manufacturing in Lancaster, CA. BYD's clean energy division produces battery storage stations, solar panels and LED lights. In 2003, BYD entered the automotive market and is now the largest selling domestic car manufacturer in China. Their global market strategy is focused on electric transportation, and BYD is the global leader in electric bus and taxi sales, with 5,000 orders in each segment, and trucks are its emerging segment. BYD will develop 25 vehicles under this project.

17207: Develop and Demonstrate Up to 12 Class 8 Battery Electric Drayage Trucks

Contractor: Peterbilt Motors	SCAQMD Cost-Share	$ 642,436
	Cosponsors	
	California Air Resources Board *(received as pass-through funds into Fund 67)*	5,657,564
	Bay Area Air Quality Management District	1,200,000

	(received as pass-through funds into Fund 67)	
	San Joaquin Air Pollution Control District *(received as pass-through funds into Fund 67)*	300,000
	San Diego Air Pollution Control District/San Diego Gas & Electric *(received as pass-through funds into Fund 67)*	200,000
	Peterbilt Motors	3,006,340
Term: 04/04/17 – 10/06/23	Total Cost:	$ 11,006,340

Peterbilt will develop 12 Class 8 battery electric trucks, which will be placed into demonstration in real-world drayage service with fleet operation in port regions throughout California. The drive system of the demonstration vehicles will be powered by an innovative dual-motor combination rated at 300kW and equipped with Inverter-Charger Units that combine the functions of the vehicle inverter and battery charger, reducing capital costs and simplifying charging logistics. The battery packs in eight of the trucks will have approximately 215kWh in total capacity, providing an estimated 70-80 miles of all-electric range under normal conditions. The remaining trucks will have increased capacity of battery packs up to 320kWh and extended total operating range to approximately 100-120 miles. A proprietary vehicle control system will optimize vehicle efficiency, maximize battery life and protect key components, such as batteries and power electronics from excessive temperatures, voltage spikes or current surges.

17225: Develop and Demonstrate Up to Two Class 8 Battery Electric Drayage Trucks

Contractor: Volvo Technology of America LLC	SCAQMD Cost-Share	$ 1,741,184
	Cosponsors	
	California Air Resources Board *(received as pass-through funds into Fund 67)*	5,657,564
	Bay Area Air Quality Management District *(received as pass-through funds into Fund 67)*	300,000
	San Diego Air Pollution Control District/San Diego Gas & Electric *(received as pass-through funds into Fund 67)*	300,000
	Volvo Technology of America LLC	1,459,698
Term: 06/09/17 – 06/08/20	Total Cost:	$ 9,458,446

Volvo is building on their PHEV diesel hybrid Class 8 truck developed under a SCAQMD/DOE grant. Volvo proposes to continue refinement towards commercialization, including integration of innovative and significant C-ITS efficiency measures, in cooperation with LA Metro. The Volvo Group's

combined market share for North American heavy-duty trucks is over 20%. Volvo will develop two trucks under this project but move through several critical internal product development "gates."

17224: Develop and Demonstrate Up to Two Class 8 Battery Electric Drayage Trucks

Contractor: Kenworth Truck Company	SCAQMD Cost-Share	$ 2,823,475
	Cosponsors	
	California Air Resources Board *(received as pass-through funds into Fund 67)*	5,714,264
	Bay Area Air Quality Management District *(received as pass-through funds into Fund 67)*	300,000
	San Joaquin Air Pollution Control District *(received as pass-through funds into Fund 67)*	300,000
	Kenworth Truck Company	606,000
Term: 09/08/17 – 01/08/20	Total Cost:	$ 9,743,739

Kenworth will develop four Class 8 plug-in hybrid electric trucks with zero emission operation capability for demonstration in revenue drayage service. The proposed fleet is intended to operate in all-electric and in conventional hybrid electric mode using a CNG engine. This fleet provides an opportunity to test the manufacturing processes for repeatability, optimize an architecture developed for this application and re-introduce field operations to this type of product. The power output of the electric drivetrain is comparable to standard Class 8 vehicles, but it will have a greater operating efficiency and improved fuel economy.

17353: Develop and Demonstrate Medium-Heavy Duty (Class 5-7) Plug-In Hybrid Electric Vehicles for Work Truck Applications

Contractor: Odyne Systems, LLC	SCAQMD Cost-Share	$ 900,000
	Cosponsors	
	Department of Energy	2,932,193
	Odyne Systems, LLC	1,033,088
	Freightliner	65,000
	Allison Transmission	25,000
	Sempra Energy (in-kind)	1,000,000
	Duke Energy (in-kind)	1,000,000
Term: 06/09/17 – 09/08/20	Total Cost:	$ 6,955,281

Odyne partners with the Freightliner Trucks, Allison Transmission, National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL), Duke Energy, Sempra Energy, AVL, LG Chem and SCAQMD to design, develop and demonstrate a new generation of medium-heavy duty (Class 5-7) PHEV work truck that achieves a significant reduction in fuel consumption versus a conventional vehicle baseline. The plug-in hybrid technology will include idle reduction, launch assist,

regenerative braking, in-cab climate controls and exportable power, improving vehicle efficiency while driving and eliminating idling and emissions during operation at a jobsite. This project will address significant improvements in powertrain integration and adaptive control, a higher level of hybridization, fully electric jobsite operation and a low cost modular battery pack solution through integrated three development streams into a final vehicle.

18075: Lease Two 2017 Chevrolet Bolt All-Electric Vehicles for Three Years for TAO's Fleet Demonstration Program

Contractor: Selman Chevrolet Company	SCAQMD Cost-Share	$ 26,824
Term: 08/18/17 – 08/17/20	Total Cost:	$ 26,824

The SCAQMD operates a number of alternative fuel vehicles (AFVs) in its Fleet Demonstration Program to support the use of zero emission vehicles and bring awareness to the public of their viability. The all-new 2017 Chevrolet Bolt EV is available in all 50 states and was selected as the Green Car Journal 2017 Green Car of the Year. It uses a 60 kWh LG Chem lithium ion (nickel-manganese-cobalt) low-profile battery pack for this five-passenger crossover, providing 238 miles U.S. EPA-estimated all-electric range, with improved passenger and cargo capacity. Increased safety technology includes a rear camera mirror with wide-angle rearview and overhead view. Use of DC fast chargers to replenish the battery up to an estimated 90 miles of range in 30 minutes will be demonstrated and evaluated during lease for broader fleet implementation. Carpool lane solo-access with white carpool sticker will be utilized when out in the community.

Direct Pay: Install Electric Vehicle Supply Equipment

Contractor: Clean Fuel Connection Inc.	SCAQMD Cost-Share	$ 20,614
Term: 01/03/17 – 08/15/17	Total Cost:	$ 20,614

This project provides for the demonstration of Level 2 chargers from several manufacturers including Clipper Creek and BTC Power, Inc. Clean Fuel Connection Inc. purchased and installed one Level 2 charger at a Board Member residence to allow for demonstration of a plug-in electric vehicle and four Level 2 chargers for fleet charging at SCAQMD headquarters as part of a larger EV infrastructure installation project. These chargers have been utilized extensively by SCAQMD Board members, staff and the general public.

Direct Pay: Conduct Work for EVSE Upgrade at SCAQMD Headquarters

Contractor: Various	SCAQMD Cost-Share	$ 14,143
Term: 01/24/17 – 08/11/17	Total Cost:	$ 14,143

In support of a larger project to install 92 new Level 2 charging ports at SCAQMD headquarters for workplace, public and fleet charging, SCAQMD engaged multiple contractors for smaller tasks connected to this upgrade. These tasks included breaker certification for the replacement of a transformer in the main electrical room; restorative landscaping in several areas of the parking lot due to trenching to install electrical conduit feeding the EV chargers; purchase of several TMobile SIM cards for multiple routers to create a WiFi network to allow the EV chargers to communicate with the Greenlots network for data collection, payment transactions and future demand response capabilities; resubmittal of the construction plans to the City of Diamond Bar due to necessary changes to accommodate transformer and electrical panel changes that occurred during the project; and additional

costs for the installer Clean Fuel Connection Inc. due to scope changes in the installation phase of the project.

Direct Pay: Purchase One 2017 Chevrolet Volt EV for TAO's Fleet Demonstration Program

Contractor: Selman Chevrolet Company	SCAQMD Cost-Share	$ 38,653
Term: 09/06/17 – 09/06/17	Total Cost:	$ 38,653

As noted, the SCAQMD operates a number of AFVs including electric vehicles, fuel cell vehicles and plug-in hybrid electric vehicles. The primary objective of having these vehicles as part of the SCAQMD's Fleet Demonstration Program is to continue to support the use of zero emission vehicles and bring awareness to the public of their viability. Due to the large area covered by SCAQMD, and the trend of purchasing Chevy Volts at end-of-lease anyway, one 2017 Chevrolet Volt was purchased in order to add it permanently to the Fleet Demonstration Program and ensure the green carpool stickers could continue to be utilized when out in the community.

Fueling Infrastructure and Deployment (NG/RNG)

15541: Implement Enhanced Fleet Modernization Program

Contractor: Foundation for California Community Colleges	SCAQMD Cost-Share	$ 21,270
	Cosponsor	
	HEROS II Revenue Fund (56)	8,730
Term: 05/07/15 – 01/30/19	Total Cost:	$ 30,000

This contract was amended in 2017 to add additional funding to provide for continued contractor assistance for the implementation of SCAQMD's Enhanced Fleet Modernization Program, which is branded by SCAQMD as "Replace Your Ride". The Replace Your Ride Program provides low- and moderate-income participants with incentives up to $9,500 to replace their older, higher-emitting vehicles with cleaner, more fuel efficient vehicles. The Foundation for California Community Colleges provides direct assistance to program participants and evaluates participant applications for SCAQMD approval. More than 90% of program participants reside in disadvantaged communities and more than 85% of participants have incomes at less than 225% of the Federal Poverty Level. More than 85% of the replacement vehicles deployed through this program are advanced technology vehicles, such as hybrids, plug-in hybrids and battery-electric vehicles. The impact on NOx emission reductions is significant since the zero and near-zero vehicles being deployed replace very dirty older vehicles. In fact, the average age of the vehicles being replaced is 18 years while the average age of the replacement vehicles being deployed is 2 years.

17349: Establish Renewable Natural Gas Center

Contractor: University of California Riverside/CE-CERT	SCAQMD Cost-Share	$ 100,000
	Cosponsors	
	Southern California Gas Company	100,000
	Department of Transportation	25,000

	University of California Riverside/CE-CERT	36,110
Term: 08/03/17 – 08/02/18	Total Cost:	$ 261,110

This project supports the establishment of a Center for Renewable Natural Gas (CRNG) to study and research key renewable natural gas (RNG) production technologies in demonstration-scale testbeds to help address challenges to commercial implementation of such technologies in California and beyond. The University of California Riverside/College of Engineering–Center for Environmental Research and Technology (CE-CERT) will evaluate RNG production potentials via thermochemical conversion and power-to-gas (P2G) technologies; conduct technological and economic evaluations of high viability projects, including wells-to-wheels analyses of GHG and criteria pollutant emissions and energy use; develop a basis for the design of demonstration-scale projects; develop a roadmap that details the most feasible path towards commercialization, including technology choices, policy and regulatory barriers, timeline and financing strategies; and conduct education and outreach to the public, policymakers and other stakeholders through conferences, communications and media outlets, as well as technology demonstrations and publications.

Fuels/Emissions Studies

15680: ComZEV: Develop Detailed Technology and Economics-Based Assessment for Heavy-Duty Advanced Technology Development

Contractor: National Renewable Energy Laboratory	SCAQMD Cost-Share	$ 20,000
	Cosponsor	
	Southern California Gas Company	20,000
Term: 08/28/15 – 06/30/18	Total Cost:	$ 40,000

The objective of the Commercial Zero Emission Vehicle (ComZEV) project is to facilitate the reduction of NOx and GHG emissions through 2050 through development of a plan for the commercialization of advanced vehicle technologies in the SCAQMD's jurisdiction. Specifically, a detailed technology and economics based roadmap will be developed, focusing on identifying barriers and opportunities to match advanced technology options to key commercial medium- and heavy-duty vehicle vocations. The original scope of the ComZEV project is near to completion, analyzing five technologies: battery electric vehicles, fuel cell vehicles, ultra-low NOx compressed natural gas spark-ignited engines, ultra-low NOx diesel engines and conventional diesel (baseline) engines for four vehicle vocations - Class 5-6 medium-duty delivery vehicles and Class 8 port drayage, short haul and long haul trucks. The Southern California Gas Company (SoCalGas) approached the SCAQMD to expand the scope of the ComZEV project to add two more vehicle vocations - Class 8 refuse and transit vehicles, and one technology - the near-zero heavy-duty CNG engine with electric range extension. The additional cost of the expanded scope is $40,000, which is being shared equally by SoCalGas and SCAQMD. SoCalGas is providing its cost-share for the expanded project directly to NREL. This amendment also provided additional time through June 30, 2018, to complete the expanded scope of work.

17245: Conduct In-Use Emissions Testing and Fuel Usage Profile of On-Road Heavy-Duty Vehicles

Contractor: West Virginia University Research Corporation	SCAQMD Cost-Share *(partially received as pass-through funds)*	$ 1,625,000

Term: 04/14/17 – 10/31/18	Total Cost:	$ 1,625,000

On-road heavy-duty engines are now subject to the 2010 U.S. EPA emissions standards of 0.2 g/bhp-hr NOx and 0.01 g/bhp-hr PM. However, engine manufacturers are still using emission credits which allow them to produce a mixture of engines certified at or below the 2010 NOx emission standard of 0.2 g/bhp-hr NOx and engines certified at a level higher than 0.2 g NOx to comply with emission standards on an average basis. While recent studies have shown NOx and PM emissions are reduced from heavy-duty vehicles powered by modern technology engines, emissions from heavy-duty vehicles still dominate the total basinwide NOx and PM emissions. In addition, a new heavy-duty natural gas engine recently certified by CARB achieves a 90% lower NOx emissions level than the current 2010 engine emission standard. Therefore, additional assessment of in-use vehicle emissions remains a critical component for measuring the effectiveness of engine, fuel and aftertreatment technologies and improving emission inventories for air quality modeling and planning as well as developing effective strategies toward achieving the federal ambient air quality standards. This project is to conduct in-use emissions testing, characterize fuel usage profiles, develop new or improve existing heavy-duty vehicle drive cycles, and assess the impact of current technology and alternative fuels on fuel consumption and in-use emissions from on-road heavy-duty vehicles with a gross vehicle weight rating of greater than 14,000 lb. To achieve this objective, the proposed project is designed to involve up to 200 on-road heavy-duty vehicles used in transit, school bus, refuse, delivery and goods movement applications and powered by engines fueled with alternative fuels, conventional and alternative diesel fuels, and a combination of diesel and natural gas (dual) fuels. The engines will be categorized into six groups including natural gas engines certified at or below 0.2 g/bhp-hr NOx, engines certified at or below 0.02 g/bhp-hr NOx, diesel engines certified at or below 0.2 g/bhp-hr NOx, diesel engines without selective catalytic reduction, dual fuel engines and alternative fuel engines (hybrid and fully electric technology). Because of the complexity and breadth of the proposed project, West Virginia University and the University of California Riverside/CE-CERT were selected to complete the project in a timely manner. Using two contractors also provides redundancy needed in such projects to measure reliability of the test results and guarantee quality assurance. SCAQMD's cost-share from the Clean Fuels Fund (31) was $300,000. Additionally, pass through funding for this project was received into the Clean Fuels Fund (31) from the following cost-share partners: California Energy Commission - $1,000,000; Southern California Gas Company - $250,000; and California Air Resources Board - $75,000.

17276: Develop ECO-ITS Strategies for Cargo Containers

Contractor: University of California Riverside/CE-CERT	SCAQMD Cost-Share	$ 543,000
	Cosponsor	
	California Energy Commission	1,647,233
Term: 08/03/17 – 08/02/20	Total Cost:	$ 2,190,233

This project is to develop and demonstrate more comprehensive ECO-ITS freight strategies, complementing the CEC-funded ECO-FRATIS Program. Specifically, UCR/CE-CERT will design and evaluate the user interface of a truck eco-approach and departure application for real-world implementation along goods movement corridors. The ECO-ITS strategies will investigate how advanced truck technologies, such as electric and hybrid trucks, can be integrated into a dynamic routing system by integrating eco-routing algorithms into a truck scheduling and routing system. Based on the evaluation results, UCR/CE-CERT will provide recommendations on the effective use of the ECO-ITS freight strategies to reduce fuel consumption as well as GHGs and criteria pollutant emissions from goods movement operations.

17277: Conduct Market Analysis for Zero Emission Heavy-Duty Trucks in Goods Movement

Contractor: University of Southern California	SCAQMD Cost-Share	$ 350,000
	Cosponsor	
	California Energy Commission	174,000
Term: 11/03/17 – 11/02/19	Total Cost:	$ 524,000

The University of Southern California (USC) will develop strategies to improve urban freight system efficiency by incorporating a centrally coordinated load-balancing system. In the proposed system, a central coordinator with access to information from all parties involved, including port terminals, trucking fleets and railyards, will be responsible for coordinating freight assignments across routes, time periods and transport modes to achieve optimum load-balancing strategies. The system will take advantage of computational capabilities and high fidelity simulation models of the road and rail networks in order to make more reliable decisions than those offered by traditional approaches. USC will also investigate the impact of new technologies, such as electric and hybrid electric trucks, on load balancing and management. This project aims to identify the best use of these trucks in combination with conventional trucks to achieve desired energy efficiency and reductions in criteria pollutants and GHGs.

17278: Develop Freight Loading Strategies for Zero Emissions Heavy-Duty Trucks in Goods Movement

Contractor: University of Southern California	SCAQMD Cost-Share	$ 200,000
	Cosponsor	
	California Energy Commission	801,000
Term: 11/03/17 – 11/02/19	Total Cost:	$ 1,001,000

USC proposes to examine the potential for zero emission and near-zero emission truck technologies from both economic and environmental perspectives, focusing on their use in short-haul drayage service. This research will take place in two parts. The first part will be to analyze potential markets; the second part, to examine effective incentives to accelerate market penetration. The simulation models will be used to estimate the impacts of using zero emission vehicles relative to conventional diesel trucks and estimate the purchase and operation costs for various scenarios to identify the best potential markets. USC will use demonstration vehicles from current SCAQMD projects, involving collectively over 60 electric and hybrid-electric drayage trucks as the vehicle and service types for this research, providing directly relevant analysis and strategies for the SCAQMD-funded trucks.

17286: Conduct In-Use Emissions Testing and Fuel Usage Profile of On-Road Heavy-Duty Vehicles

Contractor: University of California Riverside/CE-CERT	SCAQMD Cost-Share *(partially received as pass-through funds)*	$ 1,625,000
Term: 06/09/17 – 12/08/18	Total Cost:	$ 1,625,000

As noted in the project summary for West Virginia University Contract # 07245 above, this project, which involves up to 200 on-road heavy-duty vehicles used in transit, school bus, refuse, delivery and goods movement applications and powered by engines fueled with alternative fuels, conventional and alternative diesel fuels, is to conduct in-use emissions testing, characterize fuel usage profiles, develop new or improve existing heavy-duty vehicle drive cycles, and assess the impact of current technology and alternative fuels on fuel consumption and in-use emissions from on-road heavy-duty vehicles with a gross vehicle weight rating of greater than 14,000 lb. Using both West Virginia University and the University of California Riverside/CE-CERT provides redundancy needed in such projects to measure reliability of the test results and guarantee quality assurance. And just like West Virginia University's contract, SCAQMD's cost-share from the Clean Fuels Fund (31) was $300,000, with pass through funding received into the Clean Fuels Fund (31) from the following cost-share partners: California Energy Commission - $1,000,000; Southern California Gas Company - $250,000; and California Air Resources Board - $75,000.

17331: Conduct In-Use PM Emissions Study for Gasoline Direct Injection Vehicles

Contractor: University of California/CE-CERT	SCAQMD Cost-Share	$ 222,000
	Cosponsor	
	Manufacturers of Emission Controls Association (MECA)	51,000
Term: 07/14/17 – 07/31/18	Total Cost:	$ 273,000

Currently, there is an increased concern about the degradation of the actual atmospheric pollution levels of NOx and 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. SCAQMD, in partnership with the University of California Riverside and MECA, will conduct this in-use real-world driving test study using three light-duty GDI vehicles - two GDI vehicles complying with the 2017 PM mass emissions standards of three mg/mile and one 'Tier 3-like' vehicle with an older model year. Specifically, the vehicles will be tested on routes representing many different driving requirements using the latest PEMS technology. A baseline test will be performed and then an external PM filter will also be added and tested under the same driving route. The results should yield a better understanding of in-use emissions during real-time driving conditions.

17352: Develop and Demonstrate Vessel Performance Management Software and Equipment

Contractor: California State University Maritime Academy	SCAQMD Cost-Share *(all transferred from BP ARCO Settlement Projects Fund 46)*	$ 50,086
	Cosponsors	
	Bay Area Air Quality Management District (cash and in-kind)	66,518
	Federal Maritime Administration (MARAD)	79,311
Term: 06/09/17 – 06/08/21	Total Cost:	$ 195,915

Ocean Going Vessels (OGVs) are very large vessels designed for deep water navigation. OGVs include large cargo vessels such as container vessels, tankers, bulk carriers and car carriers, as well as passenger cruise vessels. These vessels transport containerized cargo; bulk items such as vehicles, cement, and coke; liquids such as oil and petrochemicals; and passengers. OGVs travel internationally and may be registered by the U.S. Coast Guard (U.S.-flagged), or under the flag of another country (foreign-flagged). The majority of vessels that visit California ports are foreign-flagged vessels, and local ports are considering various approaches to incentivizing cleaner OGVs. This project proposes to demonstrate a technology capable of harvesting high altitude wind energy while employing a vessel performance optimization system. The first phase of the project includes the design and installation of the performance management software and equipment followed by demonstration of the equipment with performance evaluation of its fuel and emissions reductions capabilities. The installation of this system is designed to enable smarter decisions while at sea, by providing real-time data point-related fuel consumption, engine performance along with external information, such as weather, to optimize ship speed, route plan, trim and energy management. The results of this study will quantify lower fuel use by the Training Ship Golden Bear on its summer cruises and help to improve air quality in coastal communities by increasing efficiency of OGVs.

18090: Study Secondary Organic Aerosol Formation from Heavy-Duty Diesel and Natural Gas Vehicles

Contractor: University of California Riverside/CE-CERT	SCAQMD Cost-Share	$ 85,000
Term: 12/05/17 – 12/04/18	Total Cost:	$ 85,000

On-road heavy-duty vehicles are currently one of the largest sources of NOx and PM emissions, which are major contributors to secondary organic aerosol (SOA) formation, along with some volatile and semi-volatile organic compounds. SOA formed from atmospheric reactions of organic compounds in the presence of NOx constitutes an important component of suspended fine atmospheric PM with significant environmental risks, such as respiratory and heart diseases as well as visibility degradation. Design of an effective emission control strategy to reduce SOA emissions and associated risks necessitates further understanding of the formation of SOA in the atmosphere. Complementary to the ongoing emissions study to assess in-use emissions from heavy duty vehicles, this project will investigate the physical and chemical composition of SOA formed by the reaction of gaseous and particulate emissions from heavy-duty diesel and natural gas vehicles. During the vehicle in-use emissions testing, the University of California Riverside/CE-CERT will collect samples of exhaust gases in a mobile chamber and transport the chamber to an atmospheric processes laboratory where the samples will be photochemically aged and characterized. During the aging process, the University of California Riverside/CE-CERT will also classify the aerosol and measure the size, mass and composition distribution of the non-refractory aerosol as well as gaseous, particulate size distribution and black carbon emissions. The results of this study will provide valuable information on primary and secondary particulate emissions including SOA from in-use heavy-duty diesel and natural gas vehicles and facilitate a discussion on potential mitigation strategies.

Technology Assessment and Transfer/Outreach

17037: Technical Assistance with Alternative Fuels, Electric Vehicles, Charging and Fueling Infrastructure and Renewable Energy

Contractor: Clean Fuel Connection Inc.	SCAQMD Cost-Share	$ 50,000
Term: 11/18/16 – 11/17/18	Total Cost:	$ 50,000

This level-of-effort contract was amended in 2017 to add an additional $50,000 for Clean Fuel Connection Inc. (CFCI) to continue to provide technical assistance with alternative fuels, electric vehicles, charging and fueling infrastructure and renewable energy. Ms. Enid Joffe (principal) has more than 15 years of experience with low and zero emission technologies, electric vehicles and charging infrastructure and renewable energy.

17097: Technical Assistance with Alternative Fuels and Fueling Infrastructure, Emissions Analysis and On-Road Sources

Contractor: Gladstein, Neandross & Associates LLC	SCAQMD Cost-Share	$ 100,000
Term: 11/04/16 – 11/03/18	Total Cost:	$ 100,000

This level-of-effort contract leverages staff resources with specialized outside expertise. Gladstein, Neandross & Associates LLC (GNA) has previously assisted SCAQMD 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. On 8/14/17, this contract was amended adding $50,000 to augment resources working on an in-use emissions study being conducted by SCAQMD. Similar to AEE Solutions (Contract #17358), GNA will be assisting with: 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. On 10/5/17, this contract was amended for a second time adding another $50,000 to continue this work as well as to continue to provide specialized outside expertise on an as-needed basis.

17336: Conduct Education Outreach for the Basin DC Fast Charging Network Project

Contractor: Three Squares Inc.	SCAQMD Cost-Share	$ 64,183
Term: 05/12/17 – 06/30/18	Total Cost:	$ 64,183

Three Squares Inc. (TSI) was selected through an RFP process to conduct a DC fast charger education outreach campaign as part of SCAQMD's cost-share for two CEC-funded grants to install a DC fast charging network. The education outreach campaign educated EV drivers and the general public on the differences between Level 1, Level 2 and DC fast charging, benefits of public charging to increase electric vehicle miles traveled, availability of public charging to supplement residential and/or workplace charging, environmental benefits associated with the use of plug-in electric vehicles and electric vehicle infrastructure, and charging etiquette. TSI created a SoCalFast website to collect information on charging and make it easily accessible to mainstream consumers and reached out and coordinated with local governments, utilities, OEMs, advocacy group, and event organizers to publicize installation of DC fast chargers. These include a traditional press event and ribbon cutting at Calabasas City Hall and EV awareness events in conjunction with the Coachella Music Festival weekends for the fast chargers in Palm Springs and Palm Desert as well as an online EV awareness event for Mel's Diner in West Hollywood. Under this contract, TSI will continue to organize EV awareness events as future fast chargers are installed, both separately and as part of an overall traditional and online social media campaign. This work was initially started under Contract #14185.

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

Contractor: AEE Solutions, LLC	SCAQMD Cost-Share	$ 100,000
Term: 06/09/17 – 06/08/19	Total Cost:	$ 100,000

This contract leverages staff resources with specialized outside expertise. Under this contract, AEE Solutions, LLC, will provide technical assistance for the in-use emissions study under this existing Board-approved technical assistance contract. Specifically, AEE Solutions will assist 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 on 6/9/17 for $50,000. In light of the additional work needed, a subsequent amendment was executed on 9/13/17 for an additional $50,000.

18019: Technical Assistance with Heavy-Duty Vehicle Emissions Testing, Analysis and Engine Development and Applications

Contractor: Ricardo Inc.	SCAQMD Cost-Share	$ 50,000
Term: 09/01/07 – 08/31/19	Total Cost:	$ 50,000

Mobile sources emit the majority of air pollution in the South Coast Air Basin (Basin). In particular, heavy-duty diesel vehicles emit high levels of nitrogen oxides (NOx), a precursor to photochemical smog, as well as diesel particulate exhaust, which has been categorized by CARB as a toxic air contaminant. The 2106 AQMP 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, SCAQMD seeks to implement aggressive programs to develop and demonstrate pre-commercial technologies as well as incentivize early-commercial technologies. Due to the rapid pace at which technologies are evolving, additional assistance is required for advanced, pre-commercial technology demonstration programs. To promote, fund, manage and expedite the development and demonstration of such advanced technology projects, SCAQMD relies on expert input and consultation. Ricardo Inc. has expertise in the areas of alternative fuels, low and zero emission technologies, emission controls, federal policies and state regulations. Under this contract, Ricardo Inc. will provide technical expertise across a broad spectrum of emission reduction technologies, including alternative and renewable fuels and fueling infrastructure, emissions analysis, and on- and off-road heavy-duty sources on an-as-needed basis.

Direct Pay: Insurance for Alternative Fuel Vehicles in TAO's Fleet Demonstration Program

Contractor: Hartford/Alliant Insurance	SCAQMD Cost-Share	$ 40,000
Term: 01/01/17- 12/3/17	Total Cost:	$ 40,000

In order to showcase and demonstrate advanced, low emission technologies, the SCAQMD often leases and/or purchases clean alternative fuel vehicles to educate public and private organizations on the

benefits of advanced technologies, as well as provide valuable in-use test data to the manufacturers. These vehicles are displayed at outreach events and conferences, used in Ride-and-Drive demonstrations, and are part of the SCAQMD carpool fleet. Private insurance is obtained for these advanced technology vehicles to ensure proper coverage.

Direct Pay: Cosponsor 22 Conferences, Workshops & Events plus 5 Memberships

Contractor: Various	SCAQMD Cost-Share	$ 324,804
	Cosponsors	0
	Various	4,131,951
Term: 01/01/17 – 12/31/17	Total Cost:	$ 4,456,755

The SCAQMD regularly participates in and hosts or cosponsors conferences, workshops and miscellaneous events. These funds provide support for the 22 conferences, workshops and events sponsored throughout 2017 as follows: Coordinating Research Council's 2017 Mobile Source Air Toxics Workshop in February and their Real World Emissions Workshop in March; University of California Irvine's ICEPAG Conference & Expo in March; University of California Riverside's 2017 Portable Emissions Measurement Systems (PEMS) Conference & Workshop in March; California Science Fair Awards in April; Transportation Research Board's Minority Student Fellow; Clean Fuels Advisory Group retreats in September 2016 and January and September 2017; Whittier Uptown Association's Whittier Earth Day in April; the Emerging Technologies Summit in April; CAPCOA's 2017 Grants 7 Mobile Sources Conference in April; GNA's Act Expo in May; California Hydrogen Business Council's Hydrogen and Fuel Cell On-Road Freight Workshop in May; FuturePorts Annual Conference 2017 in June; University of California Davis/ITS' The Asilomar 2017 Conference on Transportation & Energy Policy in August; Southern California Chinese American Environmental Protection Association's 2017 Los Angeles Environmental Forum in August; 2017 Women in Green Forum; Plug-In America's Los Angeles National Drive Electric Week; Platia Productions' 2017 Santa Monica AltCar Expo & Conference in September; SustainOC's 2017 Advanced Transportation Symposium and Expo in September; Calstart's 25th Anniversary Symposium in October; CalETC's 2017 Los Angeles Auto Show panel; and BRC's Southern California Energy Water & Green Living Summit in January 2018. Additionally, for 2017 four memberships were renewed for participation in the Plug-In Electrict Vehicle (PEV) Collaborative, California Hydrogen Business Council, Fuel Cell Hydrogen Energy Association, Calstart and the California Stationary Fuel Cell Collaborative.

CLEAN FUELS PROGRAM
Progress and Results in 2017

Key Projects Completed

A large number of emission sources contribute to the air quality problems in the South Coast Air Basin. Given the diversity of these sources, there is no single technology or "silver bullet" that can solve all of the region's problems. Accordingly, the SCAQMD continues to support a wide range of advanced technologies, addressing not only the diversity of emissions sources, but also the time frame to commercialization of these technologies. Projects cofunded by the SCAQMD's Clean Fuels Program include emission reduction demonstrations for both mobile and stationary sources, although legislative requirements limit the use of available funds primarily to on-road mobile sources.

Historically, mobile source projects have targeted low-emission technology developments in automobiles, transit buses, medium- and heavy-duty trucks and off-road applications. These vehicle-related efforts have focused on: 1) Development, Integration and Demonstration of Ultra-Low Emission Natural Gas Engines Certified for Production; 2) Replacement and Demonstration of UPS Diesel Delivery Trucks with Zero Emission Medium-Duty Trucks; 3) Zero Emission Cargo Transport Demonstration; and 4) .

Table 5 (page 72) provides a list of 43 projects and contracts completed in 2017. Summaries of the completed technical projects are included in Appendix C. Selected projects which represent a range of key technologies from near-term to long-term are highlighted below.

Development, Integration and Demonstration of Ultra-Low Emission Natural Gas Engines Certified for Production

Heavy-duty on-road vehicles represent one of the largest sources of NOx emissions and fuel consumption in North America. Heavy-duty vehicles are predominantly diesels. As emissions and greenhouse gas regulations continue to tighten, new opportunities for advanced fleet specific heavy-duty vehicles are becoming available with improved fuel economy. NOx emissions have dropped significantly from heavy-duty vehicles with the 2010 heavy-duty engine standard; however, additional NOx reductions of another 90% are necessary for the South Coast Air Basin to meet goals in the 2016 AQMP.

Although the 2010 certification standards were designed to reduce NOx emissions, subsequent studies have shown that in-use NOx emissions are actually much higher than standard. The main reason is a result of the poor performance of aftertreatment systems for diesel vehicles during low temperature and load operation. Recent studies by UCR suggest 99% of the operation within 10 miles of the ports represents up to 1 g/bhp-hr NOx for some diesel trucks. Thus, a real NOx success will not only be providing a solution that is independent of duty cycle, but one that also reduces the emissions an additional 90%. It is expected natural gas vehicles could play a role in the reduction of the South Coast NOx inventory problem.

In July 2015, the Board awarded a contract to Cummins Westport Inc. (CWI) to develop and demonstrate an ultra-low NOx emission 8.9L natural gas engine. The objectives of this project were to:

- Design, develop and demonstrate an ultra-low emissions, commercially viable natural gas engine suitable for on-road heavy duty vehicle applications;
- Achieve emissions targets of 0.02 g/bhp·hr NOx, 0.01 g/bhp·hr PM, 0.14 g/bhp hr NMHC, and 15.5 g/bhp·hr CO or lower as determined by the heavy-duty engine FTP;

- Keep exhaust NH3 emissions as low as achievable while targeting NH3 emissions at 10 ppm or lower;
- Achieve thermal efficiency and incorporate methods to achieve minimal (or zero) fuel economy penalties relative to 2010 U.S. EPA and CARB-certified diesel engines in similar duty cycles; and
- Obtain certification by the U.S. EPA and CARB.

The project was completed in July 2017 with a cumulative log of 581,963 miles. The ISL G NZ 8.9L natural gas engine met and exceeded the target NOx emissions of 0.02 g/bhp-hr and maintained those emissions during a full ration of duty cycles found in the South Coast Air Basin.

- A peak rating of 320 horsepower and 1,000 feet per pound of torque.
- Fuel consumption and mileage data from San Diego Transit indicated they were achieving 3.39 to 3.83 MPGde in a transit application. UCR's testing indicated the MPG on a diesel gallon equivalent (DGE) - assuming 2,863 gram NG/gallon diesel ranges - from 4.5 MPGde for the regional port cycle (DPT3) to 2.5 MPGde for CBD cycle.
- In late 2015, CWI obtained certification of the 8.9L engine from both CARB and U.S. EPA. While the certification is at CARB's Optional Low NOx 0.02 gram standard, actual results were lower than CARB's optional low NOx standard, and the resulting engine has a reduction of over 90% NOx from current federal standards.

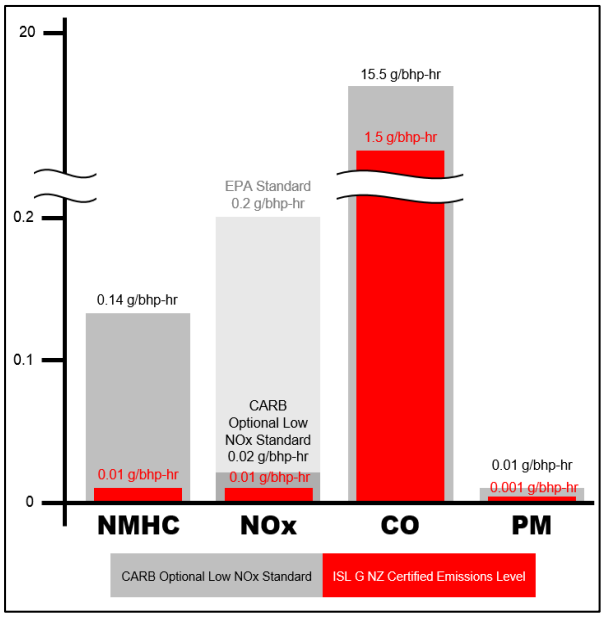


Figure 33: Certified 8.9L NG engine, below CARB's Optional Low NOx Standard

chassis resulting in commercial availability of vehicles powered by the ISL G near-zero engine.

Furthermore, on a related note, in May 2013, SCAQMD released a RFP to develop and demonstrate certified ultra-low NOx natural gas engines for on-road use. Since then, an 8.9L engine was certified and is in full production. Other technologies and engines were also investigated at this time leading to future potential projects.

Following the development work and in parallel with the demonstration work conducted as part of this project, full commercialization tasks were undertaken and completed resulting in the ISL G ultra-low NOx engine entering production in the spring of 2016. The engine was then integrated into vehicles, such as refuse trucks and transit buses, and demonstrated until July 2017. The vehicles were existing OEM customers who integrated the ISL G near-zero in their vehicle

Figure 34: Full Production 2018, 8.9-L Natural Gas Engine Certified at 0.02 g/bhp-hr NOx Emissions

Success in ultra-low NOx engine development and demonstration is continuing with CWI in a follow-on project to develop a 12L natural gas engine for heavy-duty trucks. The 12L has received CARB and U.S. EPA certification at 0.02 g/bhp-hr NOx and is currently being demonstrated in the ports and other truck applications. The 12L engine is expected to go into full production early 2018 when it will be commercially available for drayage trucks and 60-foot articulated transit buses. SCAQMD has various incentive programs (e.g., Carl Moyer Program) to assist in pushing penetration of these engines into the marketplace including into large fleet service. These incentives, which help accelerate fleet turnover, offer an opportunity for greater emissions reductions sooner and, as noted earlier, together with the Clean Fuels Program create a unique synergy.

Replacement and Demonstration of UPS Diesel Delivery Trucks with Zero Emission Medium-Duty Trucks

In 2011, Electric Vehicle International (EVI) and UPS began working with the SCAQMD to identify a partnership that would provide incentive funding for UPS and in return put clean, zero emission vehicles on the road. The SCAQMD Board approved a $1.4 million grant to help UPS replace diesel trucks with all electric vehicles in San Bernardino. The Zero Emission Community-Level Goods Movement and Delivery Demonstration was a five-year project that replaced older UPS vehicles with 40 of EVI's clean medium-duty vehicles and provided vehicle and environmental savings data to the SCAQMD. The Zero Emission Community-Level Goods Movement and Delivery Demonstration was a collaborative funding effort including the SCAQMD, CARB's Resource Board Hybrid Truck and Bus Voucher Inventive Project (HVIP), the California Energy Commission through its Diesel Emissions Reduction Act (DERA) Program, UPS and EVI.

Figure 35: UPS P-1000 Electric Delivery Van

Figure 36:UPS Electric Van Fleet at San Bernardino Plant

One of the main objectives of this project was to decrease the localized and regional emissions created by door-to-door goods movement services. As part of this project, the emission reductions were calculated for at least five years, although the benefits to the San Bernardino community will continue for many years after the demonstration project is over. Replacing harmful diesel vehicles with similar zero emission vehicles also provided direct NOx and PM emission reductions.

As part of this project, EVI delivered two different types of clean vehicles to UPS in San Bernardino. The P1000 was equipped with 1,000 square feet of package space and the P70 had 700 square feet of package space. UPS received their first vehicle in November 2012, and in June 2013, EVI delivered the final of 40 vehicles, creating the largest, single Class 6 electric vehicle deployment in California.

As part of the initial agreement with the SCAQMD, UPS was asked to de-commission one diesel vehicle for every new zero emission vehicle received. UPS chose to de-commission 40 diesel vehicles that were built in the early 1990s.

The chart below illustrates additional emission reductions in NOx, PM2.5, HC, CO and CO2. Over the life of the vehicles in this project, the SCAQMD will have saved over 40 tons of NOx, 1.5 tons of PM2.5, 2.35 tons of HC, over 12 tons of CO and 2,110 tons of CO2.

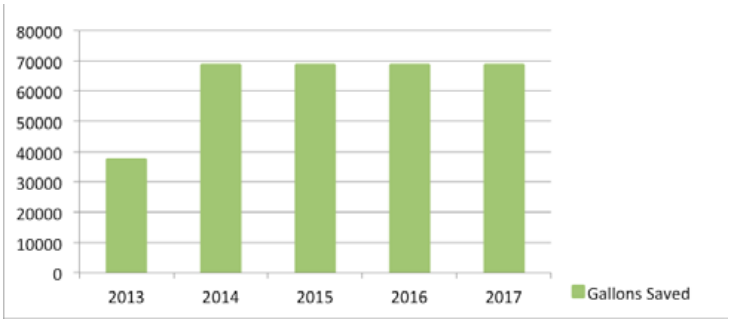
Annual	NOx (short tons/year)	PM2.5 (short tons/year)	HC (short tons/year)	CO (short tons/year)	CO2 (short tons/year)	Diesel–Equivalent (gallons/year)
Baseline of Entire Fleet	8.3894	0.3027	0.4747	2.4421	421.9776	38,016.0000
Baseline of Vehicles Retrofitted	8.3894	0.3027	0.4747	2.4421	421.9776	38,016.0000
Percent Reduced (%)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Amount Reduced Per Year	8.3894	0.3027	0.4747	2.4421	421.9776	38,016.0000

Daily	NOx (kg/day)	PM2.5 (kg/day)	HC (kg/day)	CO (kg/day)	CO2 (kg/day)	Diesel–Equivalent (gal/day)
Kilograms Reduced Per Day (kg/day)	20.8513	0.7524	1.1797	6.0698	1,048.7990	104.1534

Figure 37: Estimated Emission Reductions

Over 300,000 clean, diesel free miles were driven in 2017. In the five-year demonstration period, over 1.5 million zero emission miles were driven under this project. The zero emission miles driven saved UPS over 34,000 gallons of diesel in 2013 and is expected to save close to 70,000 for the remaining project years. Total gallons of fuel saved under this project will be over 300,000.

Figure 38: Gallons of Fuel Saved



The Zero Emission Community-Level Goods Movement and Delivery Demonstration was a first step toward transitioning more UPS vehicles to electrification. Through this successful project, we hope that more return-to-base companies will look toward electrification as a fleet vehicle option.

Zero emission, battery electric technology is still plagued with cost-effectiveness when compared to similar hybrid electric vehicles. Although the environmental savings are so much greater with all electric vehicles, hybrid electric vehicles have a much lower incremental cost increase. We can continue to drive fleet market adoption with continued partnerships and increased incentive opportunities for all electric vehicles.

EVI and UPS see continued partnerships with the SCAQMD and CARB as a catalyst to transition diesel fleets to clean electric, including fuel cell, technology in the South Coast Air Basin and throughout California.

Zero Emission Cargo Transport (ZECT) Demonstration

On-road heavy-duty diesel trucks are one of the largest sources of diesel particulate matter and NOx emissions in the South Coast Air Basin. The impact on air quality and public health is more pronounced in the surrounding communities along the goods movement corridors near the San Pedro Bay Ports - Ports of Los Angeles and Long Beach, and next to major freeways in Southern California. As a measure

to reduce the impact and meet federal ambient air quality standards, the SCAQMD has been working with regional stakeholders to promote and support the development and deployment of advanced zero emission cargo transport technologies. In 2012, SCAQMD applied for and received a $4.17 million grant from the Department of Energy under the Zero Emission Cargo Transport (ZECT) Demonstration Program to develop various Class 8 electric drayage trucks with zero emission operation capability. One of the four technologies funded by the DOE grant was battery electric trucks developed by Transportation Power, Inc. (TransPower).

In partnership with Navistar and Total Transportation Services, Inc. (TTSI), TransPower designed and manufactured pre-commercial Class 8 battery-electric drayage trucks - Electric Drayage Demonstration (EDD) trucks - and conducted a demonstration over a three-and-a-half year period in real-world drayage operation environments, transporting cargo containers in and around the Ports of Los Angeles (POLA) and Long Beach (POLB). The original project scope included only four EDD trucks, but by leveraging a grant from the CEC and additional cost-sharing from the SCAQMD and the two Ports through their Technology Advancement Program (TAP), the project later increased the demonstration fleet from three to seven trucks and extended the demonstration period by two years through September 30, 2017, to allow more time for testing of these trucks.

These trucks featured a high-power electric drive system designed and developed by TransPower and a team of U.S. based component suppliers. The EDD trucks were expected to demonstrate new industry-leading technologies and products in at least three key areas:

Power Conversion: advanced Inverter-Charger Unit (ICU) that combines the functions of vehicle inverter and battery charger with the expectation of reducing capital costs and simplifying battery recharging.

Energy Storage: high-energy battery modules using the lowest cost lithium-ion cells available, along with an advanced battery management system (BMS).

Vehicle Control: a proprietary vehicle control system to optimize vehicle efficiency, maximize battery life and protect key components such as batteries and power electronics from excessive temperatures, voltage spikes or current surges.

Figure 39: First Four EDD Trucks (March 2015)

The demonstration activities were conducted under real-world cargo transport conditions at the San Pedro Bay Ports. The trucks were projected to provide 100 miles of daily operating range under normal conditions and 60-65 miles of range under fully-loaded conditions, with a top speed of at least 60 mph and significantly faster acceleration than conventional diesel trucks. EDD-1, the first of the seven demonstration vehicles, was first deployed into drayage service in April 2014 and was demonstrated for most of 2014. EDD-1 was the evolution of TransPower's prototypes in 2011 and 2013 and utilized the latest version of TransPower's ElecTruck™ drive system. The ElecTruck™ drive system is the basis of TransPower's battery electric vehicle drive system and consists of three major subsystems. (1) the Power Control and Accessory Subsystem (PCAS) that combines a network control architecture, control software, and power conversion modules into an integrated subsystem that links all drive system components and enables them to communicate with vehicle controls and displays. A key component of the PCAS is an onboard Inverter-Charger Unit (ICU) developed with EPC Power Corp. (2) the Motive

Drive Subsystem (MDS) that converts electrical power from the battery subsystem and ICU into mechanical power to drive the vehicle's wheels. The MDS makes innovative use of a motor originally designed for a high-performance hybrid passenger car--the Fisker Karma. Developed and supplied by Quantum Technologies, TransPower used two of these motors, each providing 150 kW of peak power, to meet the demanding truck requirements. TransPower developed a proprietary means of mounting the two motors in tandem with a through shaft which is then mated to an Eaton 10-speed "automated manual transmission" (AMT); this represented a major industry innovation and a huge improvement over the gearbox installed into TransPower's first prototype Class 8 truck. (3) The Energy Storage Subsystem (ESS), which includes the batteries and interconnects. Each sub-system was continually assessed for improvement during the ZECT Demonstration Program.

Figure 40: EDD Truck Carrying a Load of Steel

Developing a reliable, cost effective ESS turned out to be the greatest engineering challenge of the ZECT project. A small module battery installation design used in EDD-1 was based on the idea that these modules afforded greater interchangeability between different types of vehicles and possibly even used in stationary battery energy systems once their vehicle use was exhausted. A key lesson learned is that installing many separate battery modules, each with its own structure, lid and network of cables and connectors into a vehicle with limited volume, and doing so safely and with precision, is exceedingly complex. In addition, it was determined that any benefits gained by standardizing module design were largely offset by the need to build heavy-duty cradles to support the modules – cradles that need to be customized to the physical dimensions of the truck, so they can never be standardized. A major redesign of the ESS to simplify the assembly and servicing of TransPower's electric trucks resulted in development of the larger, more rugged battery enclosures used in EDD-2 and all subsequent EDD trucks (Figure 41).

Figure 41: New ESS - 5 large modules (300 Ah cells) mounted on frame rails & behind cab of EDD-2

EDD-2 was completed in August 2014 and underwent four months of drive testing and optimization of the new ESS, including the new Cell-Saver™ battery management system. The University of California Riverside (UCR) tested the truck and reported a "high degree of reliability" with the ElecTruck™ drive system. UCR concluded that the EDD-2 vehicle consumed half as much battery energy per mile relative to another battery electric truck evaluated by UCR in 2011. EDD-2 was deployed into drayage service in early 2015 and continued operating through September 2017.

In September 2015, EDD-3 was delivered to the California Cartage (CalCartage) Company in Wilmington, the largest drayage company supporting the Ports, where it began demonstration operation in October 2015. Starting in December 2015, EDD-3 initiated regular single-shift, daily operation, 6 days a week, averaging 40 miles per day and 2-4 "pulls" per 8-hour shift. Through the end of the ZECT project in September 2017, it accrued 11,703 miles and continued to perform reliably. However, CalCartage found it difficult to find uses for EDD-3 due to its range limitations.

Test operation of EDD-4 was initiated in the spring of 2015, when it was showcased at an environmental event hosted by San Diego Gas & Electric Company and used for brief demonstrations with fleet operators in the San Diego region. In September 2015, EDD-4 began performing regular demonstration service with National Retail Trucking (NRT) based in Compton, exclusively for draying IKEA containers from the various terminals at the San Pedro Bay Ports. In early 2016, EDD-4 was returned to TransPower to address an intermittent power steering fault and for planned upgrades to the ICU. After three weeks of service to address these issues, it was returned to NRT, where it operated with a high degree of reliability for the duration of the project. Through the end of the project, EDD-4 accumulated 13,195 miles of operation, including more than 12,500 miles of commercial drayage service.

EDD-5 and EDD-6 were both delivered to the Los Angeles/Long Beach port region for service in early 2016. Deployment of these trucks was delayed for several months due an unexpectedly long development cycle for the RS-12, which is the inverter-only unit that TransPower elected to introduce in these three newer trucks. The RS-12 replaced the second ICU in trucks of the EDD design, which proved to save on cost and weight without sacrificing operations because only one ICU is required for battery charging. EDD-7 was the primary truck used for this "motor characterization" testing and tuning of the ICUs and RS-12 inverters. At the conclusion of this effort, the RS-12 was actually shown to be capable of coaxing 165 kW of power out of each JJE motor, a 10% improvement over the previous peak power level of 150 kW.

The seven vehicles collectively accrued more than 43,000 miles. The first four trucks gained 37,841 miles and the remaining 3 trucks saw less mileage but helped validate the latest drive system improvements. Most of the miles accrued on the fleet of EDDs were hauling heavy loads in real-world drayage operations. The technologies used in these trucks were improved continuously throughout the project, achieving the more important goal of bringing them close to a state of commercial readiness. Many of the trucks are expected to continue routine drayage operations with TTSI under a lease agreement with TransPower.

The ZECT research added to the understanding of heavy-duty battery electric vehicle technology in many ways. TransPower continuously improved its electric drive components in response to many valuable lessons learned. Improvements were achieved in each of the principal technology areas:

Power Conversion: The ICU was improved to make it more robust, and a new control scheme was developed to control one of the truck's two motors with a smaller, less expensive inverter, rather than duplicating the battery charging hardware in the ICU. A new automotive accessory inverter was integrated into the system, replacing a failure-prone industrial inverter.

Energy Storage: Battery module designs shifted from installing batteries in a large number of small modules to using a smaller number of large battery enclosures (Figure 3). This greatly reduced the complexity of battery subsystem integration. A new advanced BMS was developed, featuring active cell balancing and high-power charge "shuffling."

Vehicle Control: A new method of mechanically integrating power control and accessory components was developed, greatly reducing the time and effort required to install these components into a truck. TransPower's automated manual transmission (AMT) system was greatly improved, with the adoption of a 10-speed Eaton transmission and refined transmission controls.

These and other improvements helped advance the state-of-the-art of electric truck component technology from early prototype/proof-of-concept to pre-commercial, where future investments can be focused on improving producibility and reducing manufacturing costs rather than demonstrating basic feasibility.

TransPower's No. 1 lesson learned from the ZECT project is that battery energy storage remains the primary technical obstacle to widespread adoption of electric trucks. Despite major investments in improving every aspect of its energy storage subsystem, variations in cell voltage and BMS failures caused problems in every truck, from the beginning of the project until the very end. While these problems were reduced in frequency and severity in six of the seven trucks over the course of the project, they remained by far the largest single cause of maintenance-related issues. The rest of the ElecTruck™ drive system was, for the most part, perfected by the end of the project and rarely caused any problems. While it is noteworthy that nearly all maintenance-related issues toward the end of the project were battery related, it should be emphasized that these problems were not the primary limitation to use of the EDD trucks. The greatest obstacle to EDD truck utilization was, by far, the limited operating range of these trucks.

The methods and techniques investigated and demonstrated in this study were shown to be highly effective technologically and economically. Prior to the ZECT project, the idea of using battery-electric technology to power Class 8 trucks weighing up to 80,000 pounds was considered impractical by many. Four years later, TransPower's fleet of electric trucks proved unequivocally that battery-electric propulsion can meet the demanding performance requirements of the heaviest Class 8 trucks, and it now appears that many new companies are entering this market such as Cummins, BYD, Daimler, Volvo and Tesla who developing and demonstrating their own electric truck systems.

The ZECT trucks were shown to be capable of hauling heavy loads with an average energy consumption of approximately 2.3 kilowatt-hours (kWh) per mile, and the base recurring cost of manufacturing an electric truck was reduced from about four times the cost of a high-end diesel truck to about twice the diesel truck cost. Extrapolations suggest that further reductions can be achieved with future modifications of TransPower components and larger scale manufacturing.

In addition to demonstrating the essential feasibility of electric Class 8 trucks the ZECT project is expected to yield public health benefits by helping to reduce emissions of carbon and criteria pollutants by large trucks. These benefits will be particularly impactful in economically and environmentally disadvantaged communities with high truck traffic, such as neighborhoods adjacent to California's seaports and near major warehouses and distribution centers. Many of these communities are in the South Coast Air Basin.

During the course of the ZECT project, the EDD trucks were operated for varying lengths of time by several fleet operators, including TTSI, CalCartage, NRT, 3 Rivers Trucking, SA Recycling, Knight Transportation Services, Pasha Stevedoring and Terminals, BAE Systems, and Terminalift. Mileage accumulations from the ZECT trucks did not measure up to initial expectations, but the experience gained while operating electric trucks in all of these fleets was invaluable. All seven trucks encountered maintenance issues of varying degrees of severity, but only one truck, EDD-1, was inoperable for an extended period of time. The other six trucks experienced reliability and maintainability issues typical for vehicles using completely new technologies, but could have been used much more extensively if not due to external factors such as limited viability of charging infrastructure, insufficient driver training/motivation, and "range anxiety." Of these factors, range anxiety was by far the most prevalent, as fleet operators had difficulty finding productive ways to operate trucks that can only operate for 60-70 miles on a single charge – the typical maximum range for an EDD truck when fully loaded.

To build on the success of the ZECT project, TransPower intends to consolidate the EDD fleet in the hands of a single fleet operator, TTSI, to make service and support easier and to achieve a "critical mass" of EV technology in one fleet. A lesson learned from the ZECT project is that when a fleet operator has only a single vehicle of a given technology type, it is difficult for that operator to divert attention from the rest of the truck in its fleet to make the continuing investments required to keep their one high-technology truck operating productively. It is hoped that deploying many of the EDD trucks with TTSI will make it more economical for TTSI to invest the resources required to keep electric

trucks operating in its fleet, and provide an opportunity to deploy the EDD trucks for limited-duty cycles.

TransPower is also pursuing development of new technologies that will directly address the shortcomings observed in the EDD fleet. These include advanced battery technologies that will extend operating range while also reducing vehicle weight and cost, and various strategies for extending operating range with onboard internal combustion engines and fuel cells. Equally important was TransPower's progress toward establishing a go-to-market strategy for commercialization of its technologies. TransPower made progress in these efforts during the ZECT project by repackaging its major subsystems in ways that will make it easier for them to be shipped to vehicle manufacturers for installation on their own assembly lines. The integrated PCAS assembly, described earlier in this report, is an excellent example of how TransPower made significant changes in its product designs and integration methods during the ZECT project to facilitate this transition, expected to be implemented in Class 8 trucks funded under other grants.

In summary, the ZECT project achieved all of its major technical and economic objectives, including demonstrating the ability of electric port drayage trucks to match or surpass the performance of conventional diesel and natural gas drayage trucks; improving reliability than previous generations of electric Class 8 trucks; zero emission operation and high energy efficiency; and quantifiable environmental and economic benefits, based on actual in-use data.

Utilization of Fleet DNA Approach and Capabilities to Provide Vehicle Vocation Analysis in the SCAQMD

According to the Energy Information Administration (EIA), diesel and gasoline account for more than 92% of the total energy used in the transportation sector. The largest consumers of fuel in the transportation sector are medium- and heavy-duty vehicles, which are also the largest contributors to NOx, PM and ozone air pollution in the South Coast and a significant source of global GHG emissions. The National Renewable Energy Laboratory (NREL) & the Department of Energy (DOE) have been conducting research, development and demonstration (RD&D) projects to facilitate the deployment of advanced vehicle technology and alternative fuels into the marketplace in order to reduce petroleum use and enhance the reduction of mobile source emissions in California and the U.S. NREL and the SCAQMD collaborated on a joint project, referred to as the Fleet DNA study, to collect data on medium- and heavy-duty vehicles used in various vocations in the South Coast; to analyze vehicle usage characteristics to better understand how vehicle vocations differ or compare; to assess their respective vehicle performances; and to provide some recommendations to improve efficiency and some technologically feasible "clean fuel" alternatives.

OEMs, commercial fleets and research organizations have identified a lack of medium- and heavy-duty vehicle use data as a barrier to intelligent vehicle design and deployment. The usage data developed in the Fleet DNA study helps to identify average and extreme use patterns for various vehicle vocations that could help identify similar use patterns across dissimilar vocations which could lead to more optimized and efficient designs that are appropriate to multiple uses. The study was intended to provide information that could enable intelligent deployment of advanced vehicle technology within key vocations. This was accomplished by showing the relationship between vocational duty cycles and technology performance.

The Fleet DNA study consisted of three parts: 1) Identification of Appropriate Vocations, 2) Data Collection and Analysis, and 3) Powertrain and Advanced Technology Matching by Vocation.

Identification of Appropriate Vocations: NREL commenced this study with an in-depth assessment of the SCAQMD vehicle population to categorize the medium- and heavy-duty (Class 3–8) on-road commercial vehicle vocations in the South Coast Air Basin. The size and age of the vehicle population

was ascertained by acquiring and mining data from the 2014 R.L. POLK medium- and heavy-duty vehicle registration database (now part of IHS Inc.). Annual vehicle miles travelled (VMT) and fuel usage numbers were estimated by leveraging data from the U.S. DOT's Vehicle In-Use Survey (VIUS) database, the Oak Ridge National Laboratory's Transportation Energy Data Book (TEDB), and CARB's EMFAC model (EMFAC is short for EMissions FACtors). To estimate NOx emissions contributions from various vehicle types, weight classes and model years, NREL developed a method to relate NOx emissions from different engine emission certification levels to fuel economy. This data was entered into NREL's Scenario Evaluation, Regionalization & Analysis (SERA) model to estimate the NOx emissions contribution from each vocational category in the SCAQMD inventory.

Results of the data mining activity using the R.L. Polk database as of April 1, 2014, produced the following results: 518,863 Class 3-8 vehicles are registered in the SCAQMD; 304,804 are registered to over 60,000 businesses, and 214,059 are registered to individuals, of which 136,685 are pre-model year (MY) 2002; the percentages of each class of vehicle in the SCAQMD fleet is comparable to those on a national level as are the percentages of Class 7-8 vehicles that meet the pre-2007, the 2007-2010, and the 2010 and newer diesel emission standards; on average, vehicles in the SCAQMD are older than the national average with 73% of Class 7-8 diesels being MY 2006 (7 years) and older and 57% being pre-MY 2002 (more than 10 years old); 65% of vehicles are registered to fleets comprising 10 or fewer vehicles.

The initial vehicle analysis led NREL to recommend and SCAQMD to agree to two scope modifications:

- Eliminate all gasoline vehicles from analysis: gasoline vehicles have significantly lower NOx impact than diesel for any given MY and are weighted towards individual ownership.
- Eliminate motorhomes from analysis: motor homes may be used sporadically and usage probably isn't confined to SCAQMD. Motor homes are weighted towards individual ownership, and there are fewer opportunities to influence this market with new low emissions technologies.

These changes reduced the Class 3-8 vehicle population by 45% (from 518,863 to 283,001) and shifted the weight class split of vehicles, reducing the Class 3-4 population the most. The selected and reduced vehicle population data was combined with VMT data from EMFAC and TEDB, fuel economy (mpg) data from TEDB, and entered into NREL's SERA model for modeling the current vehicle population's breakdown along vocation, class and vehicle type categories; generating estimated miles and fuel consumption; and, when combined with NREL's fuel consumption-to-NOx emissions correlation, estimating NOx emissions from each vehicle category. To develop its NOx vs Fuel Consumption correlation, NREL conducted an extensive literature study of chassis dyno test results. The combined studies included 277 vehicles, 29 test cycles and almost 600 individual test runs. This information was compared to corresponding engine emissions certifications levels. The derived NOx/Fuel Consumption correlation compared more favorably against engine emission certification levels for MYs 2007 and newer and less so for older vehicles.

Because Class 8 vehicles are the largest commercial vehicle population segment, travel the most miles and have the lowest average fuel economy (mpg), they are the largest NOx contributors in the vehicle population study. Class 8 vehicles comprised 50% of the Class 3-8 population and contributed 77% of vehicle NOx emissions from this population across all model years. The two figures on the next page show the vehicle population estimated aggregate NOx emissions by vehicle class and model year (Figure 42) and by vocation and model year (Figure 43).

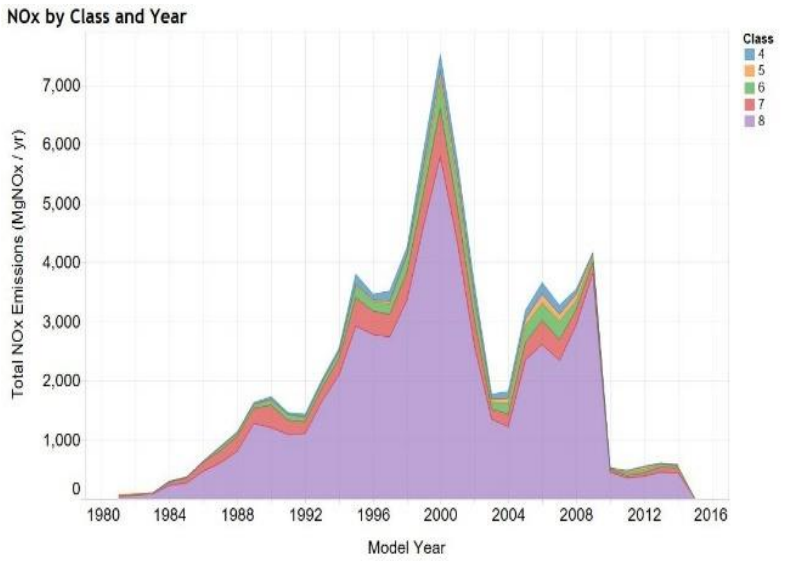


Figure 42: NOx Emissions by Vehicle Class and MY

Based on the above vehicle population and NOx inventory analysis, the following vocations were recommended for further study: Class 8 vehicles in General Freight, Services, Wholesale/Retail and Refuse vocational groups. By looking at fleets owning Class 8 vehicles under those categories, the following groups were recommended due to the presence of larger fleets: drayage/logistics fleets; auto wrecking/used auto parts fleets; and curbside refuse collection. NREL identified potential commercial fleets in the above business sectors to obtain detailed vehicle usage data. Based on a review of the NREL recommendations and other programmatic considerations, SCAQMD decided on the following fleet vocations for data collection: Class 8 drayage and transfer trucks and Class 3-7 delivery trucks.

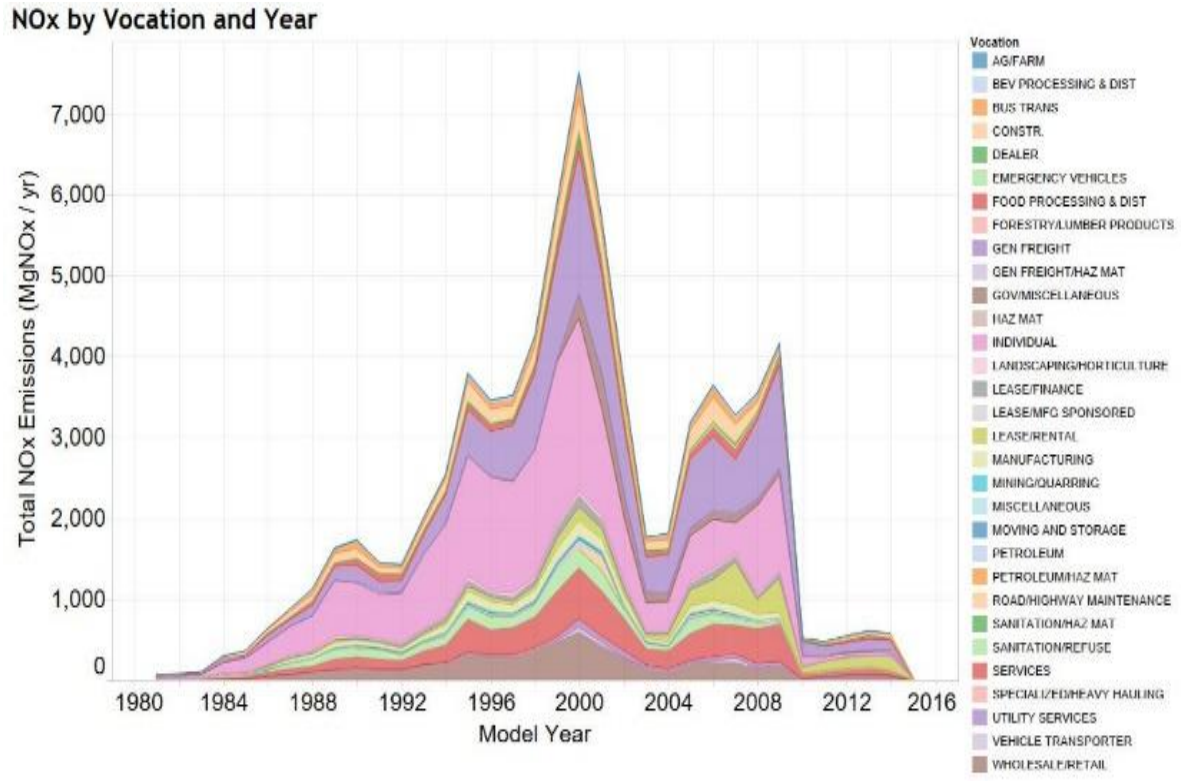


Figure 43: Annual NOx Emissions by Vocation and MY

Data Collection and Analysis: NREL completed a campaign of commercial vehicle data logging within SCAQMD to capture detailed 1 Hz GPS and engine CAN6 data on the three specified vocations: Class 8 drayage and transfer trucks and Class 3-7 delivery trucks. This effort resulted in almost 5,000 vehicle trips and over 1,500 recorded days of operation from 114 vehicles. NREL completed detailed duty-cycle analysis of each of these vocations and selected representative chassis drive cycles that could be used to evaluate technologies on vehicle platforms. NREL also leveraged recent data logging activities within these vocations and this region including data collected by NREL under the California Hybrid Truck and Bus Voucher Incentive Project (HVIP) and Phase 1 of the DOE-funded Zero Emission Cargo Transport (ZECT I). Under the HVIP, data was collected between October 2012 to September 2013 from 62 delivery vehicles for 2 to 3 weeks, each including parcel and linen delivery vocations with UPS, Aramark and FedEx. Data from the ZECT I project included datalogging of drayage service from TTSI including 149 days of conventional baseline vehicle operation on 2 trucks and 26 days of operation of the TransPower electrified drayage trucks.

NREL conducted drive cycle analysis from all vehicles within each of the three selected vocations as a group with no separation by operator or location. As would be expected, each of the three vocations has different drive cycle statistics based on their different vocational operations.

Figure 44 shows a histogram of average driven speed (not including idle time) of each vocation. Both delivery trucks and drayage trucks have average driven speeds near 30 mph, but the average driven speed of the drayage group is likely reduced by the slow speed "creep" time while in queue at or near the port. The transfer trucks have more days with average speed in the 40-50 mph range, but are still

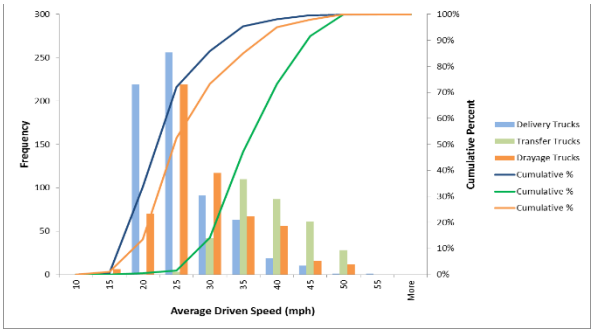


Figure 44: Average Driven Speed

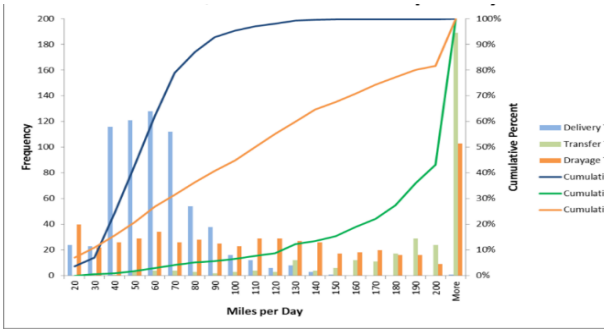


Figure 45: Miles Driven Per Day

not a pure highway driving type. NREL applied its Drive-cycle Rapid Investigation, Visualization and Evaluation tool (DRIVE™) to compare representative drive cycle metrics from the data collected for this project to a variety of standard drive cycles. Figure 45 shows a histogram of the miles driven per day by each of the vocations. The delivery group has the narrowest range of daily miles while drayage and transfer trucks have greater variation day-to-day as well as higher miles per day as would be expected. NREL used this comparison to select drive cycles that best represent and bracket the observed operational data.

Powertrain and Advanced Technology Matching by Vocation: NREL completed an extensive analysis on the impact of technology improvements on vehicle efficiency and performance using the Future Automotive Systems Technology Simulator tool (FASTSim) batch processing all the real world recorded drive cycles collected in the study. Assessed technologies included: battery electric, natural gas, aerodynamic improvements, mass reduction and rolling resistance. A brief summary of the technology trends is provided below.

[6] The Controller Area Network (CAN, also known as CAN Bus) is a vehicle data bus standard designed to allow automotive electronic control units and devices to communicate with each other.

Delivery Trucks (Class 3-7) - NREL modeled the effects of rolling resistance, aerodynamic drag, vehicle mass reduction, CNG engines and vehicle electrification across over 2100 real-world delivery truck trips in the Fleet DNA database for class 3-7 delivery trucks. The results showed that delivery trucks benefit more from mass reduction than from rolling resistance reduction or aerodynamic improvements. The stop-and-go nature of delivery vehicles means they save fuel from reduced mass on every acceleration. Conversely they do not typically drive enough miles for rolling resistance improvements to have the same impact and they do not drive enough at high speeds for aerodynamic improvements to save substantial amounts of energy. When routes are within the range of EV powertrains large savings can be realized, but payback due to the cost of batteries and electric rate structure must be considered on an individual site basis. Simulations of delivery truck routes showed EVs using significantly less energy than their diesel counterparts (approximately 1.3 kWh/mile EV vs. 4.4 kWh/mile diesel). The Fleet DNA duty cycle data showed that approximately 80% of daily driving was less than 70 miles per day, which could be accomplished with a 100kWh battery pack. CNG, while somewhat less efficient on an energy basis may offer fuel cost savings when natural gas prices remain below diesel with lower emissions relative to baseline diesel technology.

Transfer Trucks (Class 8) - NREL modeled the effects of rolling resistance, aerodynamic drag, vehicle mass reduction, and CNG engines across over 800 real-world transfer truck trips in the database. EVs were not considered because of the long daily driving distances (i.e., 90% of the daily driving was over 100 miles). The simulations showed that transfer trucks benefit more from mass reduction and rolling resistance reduction than from aerodynamic improvements; but small aerodynamic improvements may be achievable as the vocation currently has not typically implemented aerodynamic improvements even though these vehicles spend significant time at highway speeds. Care would have to be taken to implement aerodynamic solutions that improve the drag coefficient without adversely affecting the job function. While current EV technology cannot provide the range needed; CNG engines can provide the range needed with reduced emissions and possible fuel cost savings when natural gas prices remain below diesel on an energy equivalent basis.

Drayage Trucks (Class 8) - NREL modeled the effects of rolling resistance, aerodynamic drag, vehicle mass reduction, CNG engines and vehicle electrification across over 1800 real-world drayage truck trips in the database. The simulations showed that drayage trucks benefit more from mass reduction than from rolling resistance reduction or aerodynamic improvements and mass reduction on the tractor is the aspect most under the control of the fleet operator. CNG and EV powertrains offer advantages that are completely separate from the chassis and container designs. EV powertrains are a good fit for drayage vehicles if the daily driving distance is within the range of a specific vehicle design and battery usage can be maximized. CNG vehicles also work well and can provide the range needed for the full spectrum of drayage operations with reduced emissions and possible fuel cost savings for the full spectrum of routes.

The results from this study were primarily intended to show the relationship between vocational duty cycles and technology performance. A follow-on more detailed "total cost of ownership" analysis, referred to as the Commercial Zero Emission Vehicle (ComZEV) Roadmap, is currently being conducted by NREL and Ricardo Engineering to fully understand economic drivers associated with each technology option, leveraging the data and results from the FleetDNA Study. SCAQMD and the Southern California Gas Company are cosponsoring ComZEV.

Table 5: Projects Completed between January 1 & December 31, 2017

Contract	Contractor	Project Title	Date
Hydrogen and Mobile Fuel Cell Technologies and Infrastructure			
10482	California State University Los Angeles	Install and Demonstrate a PEM Electrolyzer in Los Angeles, Providing Hydrogen Fueling for Vehicles and Utilizing the Technology in the Engineering Technology Curriculum at the University	Oct-2017
13155†	Fletcher Jones Motor Cars Inc.	Lease Two F-Cell Fuel Cell Vehicles for Two Years	Feb-2017
14139†	Hyundai America Technical Center Inc.	No-Cost Lease of Fuel Cell Vehicle	Dec-2017
16039	Lawrence Livermore National Laboratory	Demonstrate Prototype Hydrogen Sensor and Electronics Package	Apr-2017
18118	Frontier Energy, Inc. (formerly BKi)	Participate in California Fuel Cell Partnership for CY 2017 and Provide Support for Regional Coordinator	Dec-2017
Engine Systems/Technologies			
15626	Cummins Westport, Inc.	Develop, Integrate and Demonstrate Ultra-Low Emission Natural Gas Engines for On-Road Heavy-Duty Vehicles	Jul-207
Electric/Hybrid Technologies and Infrastructure			
12028	Electric Vehicle International, Inc.	Demonstrate and Replace UPS Delivery Trucks with Zero Emission Medium-Duty Trucks	Sep-2017
13396	Transportation Power, Inc.	Develop and Demonstrate Seven Class 8 Zero Emission Electric Trucks	Sep-2017
14156†	Galpin Motors Inc. (Galpin Ford)	Lease Two Fusion Energi and One C-Max Energi PHEVs for a Three-Year Period	Jan-2017
14224	Complete Coach Works	Develop and Demonstrate Long Range All-Electric Transit Bus	Feb-2017
14323†	Selman Chevrolet Company	Lease Two 2014 Chevrolet Volt Extended-Range Electric Vehicles for Three Years	Mar-2017
15448†	University of California Los Angeles	Site Selection for DC Fast Charge Network	Apr-2017
Fueling Infrastructure and Deployment (NG/RNG)			
07246	USA Waste of California, Inc.	Purchase and Install New LNG Storage Tank at Long Beach LNG Refueling Station	Jun-2017
08098	Redlands Unified School District	Purchase and Install New CNG Fueling Station	Apr-2017
12135	Placentia-Yorba Linda Unified School District	Upgrade CNG Fueling Station	Nov-2017
14311	Southern California Gas Company	Construct CNG Fueling Station in Murrieta	Dec-2017

Table 5: Projects Completed between January 1 & December 31, 2017 (cont'd)

Contract	Contractor	Project Title	Date
Fuels/Emissions Studies			
10722	University of California Riverside/CE-CERT	Re-Establish Testing Facility and Quantify PM Emission Reductions from Charbroiling Operations	Sep-2017
14162	National Renewable Energy Laboratory	Utilize Fleet DNA Approach and Capabilities to Provide Vehicle Vocational Analysis within SCAQMD	Jun-2017
15623	University of California Riverside/CE-CERT	Evaluate Ozone and SOA Formation from Gasoline and Diesel Compounds	Mar-2017
16198	Gladstein, Neandross & Associates LLC	Study Opportunities and Benefits of Deploying Next Generation Heavy-Duty Natural Gas Vehicles Operating on Renewable Natural Gas	Jan-207
16254	University of California Berkeley	Evaluate Ozone and Secondary Aerosol Formation from Diesel Fuels	Dec-2017
Stationary Clean Fuel Technologies			
13408	University of California Irvine	Demonstrate Building Integration of Electric Vehicles, Photovoltaics and Stationary Fuel Cells	Sep-2017
Health Impacts Studies			
14171	Southern California Research Center/Allergy & Asthma Associates of Southern California	Study Air Pollution Health Effects on In-Utero Exposure to Traffic-Related Pollutants	May-2017
Technology Assessment and Transfer/Outreach			
05128†	Mid-Atlantic Research Institute LLC	Technical Assistance for Development, Outreach and Commercialization of Advanced Heavy-Duty and Off-Road Technologies	Mar-2017
13194†	Clean Fuel Connection Inc.	Technical Assistance with Alternative Fuels, Renewable Energy and Electric Vehicles	Mar-2017
15369†	Breakthrough Technologies Institute, Inc.	Technical Assistance with Low and Zero Emission Vehicles, Fuel Cells, Stationary Applications and Emissions Analyses	Dec-2017
15507†	Jerald A. Cole	Technical Assistance with Alternative Fuels, Emissions Analysis and Combustion Technologies	Jan-2017
15610	Goss Engineering, Inc.	Conduct Engineering Services at SCAQMD Headquarters	Dec-2017
17076†	Gladstein, Neandross & Associates, Inc.	Cosponsor Rethink Methane 2017	Apr-2017
17174†	Coordinating Research Council, Inc.	Cosponsor 27th Real-World Emissions Workshop	May-2017
17175†	Coordinating Research Council, Inc.	Cosponsor 2017 Mobile Source Air Toxics Workshop	Apr-2017

Table 5: Projects Completed between January 1 & December 31, 2017 (cont'd)

Contract	Contractor	Project Title	Date
Technology Assessment and Transfer/Outreach (cont'd)			
17275†	University of California Irvine	Cosponsor ICEPAG 2017	Sep-2017
17314†	University of California Irvine	Cosponsor the 2017 Portable Emissions Measurement Systems (PEMS) Conference & Workshop	Mar-2017
17324†	Whittier Uptown Association	Cosponsor Whittier Earth Day 2017	Oct-2017
17334†	Fourth Wall Events Inc.	Cosponsor the Emerging Technologies Summit	Apr-2017
17346†	Gladstein, Neandross & Associates LLC	Cosponsor the ACT Expo 2017	Jun-2017
17369†	FuturePorts	Cosponsor FuturePorts Annual Conference 2017	Jul-2017
17370†	Sustain OC	Cosponsor the 2017 Advanced Transportation Symposium & Expo	Aug-2017
17401†	University of California Davis-Institute of Transportation Studies	Cosponsor The Asilomar 2017 Conference on Transportation & Energy Policy	Oct-2017
18003†	Southern California Chinese American Environmental Protection Association	Cosponsor 2017 Los Angeles Environmental Forum	Sep-2017
18030†	Platia Productions	Cosponsor the 2017 Santa Monica AltCar Expo & Conference	Nov-2017
18039†	Three Squares Inc.	Cosponsor the 2017 Women in Green Forum	Nov-2017
18092†	California Electric Transportation Coalition	Cosponsor the CalETC 2017 Los Angeles Auto Show Events	Dec-2017

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

CLEAN FUELS PROGRAM
2018 Plan Update

As noted earlier, this year marks the 30th year of the SCAQMD's Clean Fuels Program, along with establishment of the Technology Advancement Office (TAO) to oversee the Program, as a result of state legislation in 1988. The funding source is a $1 motor vehicle registration surcharge that, like the Program, 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 has continued to fund a broad array of technology applications spanning near- and long-term implementation. More recently, the focus has been and will continue to be to support the development and deployment of zero and near-zero emission technologies. Similarly, planning has been and will remain an ongoing activity for the Program, which must remain flexible to address evolving technologies as well as the latest progress in the state-of-technologies, new research areas and data.

Every year the SCAQMD re-evaluates the Clean Fuels Program to develop a Plan Update based on a reassessment of the technology progress and direction of the SCAQMD's Board. This Plan Update for CY 2018 targets several near-term projects to help achieve emissions reductions needed for the South Coast to meet health-based air quality standards.

Overall Strategy

The overall strategy of the TAO's Clean Fuels Program is based, in large part, on emission reduction technology needs identified through the AQMP process and the SCAQMD Board's directives to protect the health of the approximately 17 million residents (nearly half the population of California) in the South Coast 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 SCAQMD Governing 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 reductions from federally regulated sources (e.g., aircraft, locomotives and ocean-going vessels).

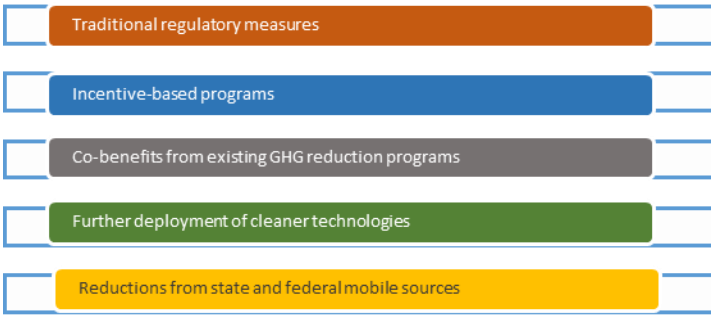


Figure 46: 2016 AQMP Components

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 projects that an approximate 45 percent reduction in NOx is required by 2023 and an additional 55 percent reduction by 2031. The majority of these NOx reductions must come from mobile sources, both on- and off-road. Notably, the SCAQMD is currently only one of two regions in the nation designated as an extreme ozone nonattainment area (the other is San Joaquin Valley). 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 especially noteworthy because in the South Coast Air Basin the primary driver for ozone formation is NOx emissions, and mobile sources contribute approximately 88 percent of the NOx emissions in this region. Furthermore, NOx emissions, along with VOC emissions, also lead to the

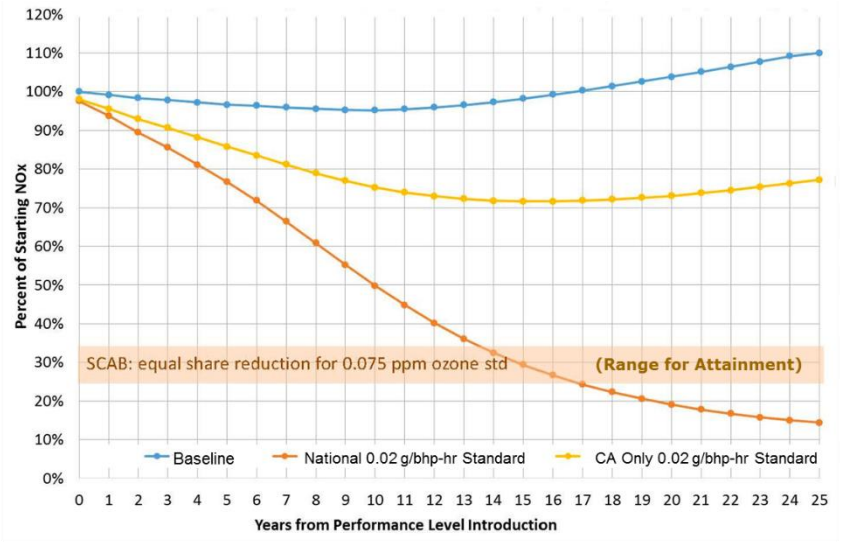
formation of PM2.5 [particulate matter measuring 2.5 microns or less in size, expressed as micrograms per cubic meter (µg/m^3)].

The 2016 AQMP includes integrated strategies and measures to demonstrate attainment of the following National Ambient Air Quality Standards (NAAQS):

- 8-hour Ozone (75 parts per billion or ppb) by 2031
- Annual PM2.5 (12 µg/m^3) by 2025
- 24-hour PM2.5 (35 µg/m^3) by 2019
- 8-hour Ozone (80 ppb) by 2023 (updated from the 2012 AQMP)
- 1-hour Ozone (120 ppb) by 2022 (updated from the 2012 AQMP)

On a positive note, the 2016 AQMP for the first time envisions Southern California achieving attainment through regulations and identifies the clean technologies to be deployed that were formerly undefined as "blackbox" measures. This is due, in part, because the needed zero and near-zero technologies are being commercialized or nearing commercialization, albeit with deployment pathways that still require more specificity and scalability. Also, additional NOx and VOC emission reduction co-benefits are expected from carbon dioxide (CO2) reductions resulting from California's climate change policies, together with funding to incentivize the deployment of these cleaner technologies. There are significant challenges to getting there, however, including the need for the U.S. EPA and CARB to lower the heavy-duty engine exhaust NOx standard from 0.2 grams per brake horsepower-hour (g/bhp-hr) to an already commercially achievable (by natural gas powered engines) 0.02 g/bhp-hr. Finally, financial resources will need to be identified that could be utilized to offset the higher procurement costs of these emerging clean technologies.

In June 2016, SCAQMD and 10 co-petitioners requested the U.S. EPA Administrator to undertake rulemaking to revise the national on-road heavy-duty engine exhaust NOx emission standard from 0.2 g/bhp-hr to 0.02 g/bhp-hr. It was recommended that the regulation be implemented by January 2022 or if not feasible, by January 2024, with a phase-in starting in January 1, 2022. A national standard (as opposed to only a California standard) is estimated to result in NOx emission reductions from this source category from 70 to 90 percent in 14 to 25 years, respectively. Given that the Basin must attain the 75 ppb ozone NAAQS by 2031 (within the next 13 years), a new on-road heavy-duty engine exhaust emissions standard for NOx is critical given the time needed for such standards to be adopted, for manufacturers to develop and produce compliant vehicles, and for national fleet turnover to occur.



Source: Presentation by Mr. Cory Palmer, ARB at the Symposium on California's Development of its Phase 2 Greenhouse

Figure 47: NOx Reduction Comparison: No New Regulations vs Low NOx Standard in California only vs National Standard

This chart here shows the difference in NOx reductions from heavy-duty trucks between baseline (no new

regulations) emissions (in blue), a low NOx standard adopted only in California (yellow) and reductions if the same low NOx standard is implemented nationally (orange).

The findings from the MATES IV[7] (released May 2015), which included local scale studies near large sources such as ports and freeways, reinforce the importance of these impacts and the need for transformative transportation technologies, especially near the goods movement corridor. In recognition of these impacts, the SCAQMD added as a key element to its strategy a concerted effort to develop and demonstrate zero and near-zero emissions' goods movement technologies, including electric trucks, plug-in hybrid trucks with all-electric range, zero emission container transport technologies, trucks operating from wayside power including catenary technology. In 2017, as noted earlier in this report, SCAQMD 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 typically emitted or converted from vehicle exhaust. CARB is also in the processing of updating its EMFAC model, which assesses emissions from on-road vehicles including cars, trucks and buses.

A key strategy of the Clean Fuels Program is its public-private partnership with private industry, technology developers, academic institutions, research institutions and government agencies. This public-private partnership has allowed the Program to leverage its funding with $3-$4 of spending on R&D projects to every $1 of SCAQMD funds. The SCAQMD aggressively seeks leverage funds to accomplish more with every dollar and will continue to do so.

CY 2018 marks another hallmark in TAO – the 20th year of the Carl Moyer Program. The Carl Moyer Program provides the necessary incentives to push market penetration of the technologies developed and demonstrated by the Clean Fuels Program. Together these two synergistic programs allow the SCAQMD to be a leader in technology development and commercialization to accelerate the reduction of criteria pollutants.

As the state government continues to turn much of their attention to climate change (CO2 reductions), the SCAQMD remains committed to developing, demonstrating and commercializing zero and near-zero emission technologies and renewable fuels. Fortunately many of the technologies that address the South Coast Basin's needed NOx reductions also enable GHG reductions. Because of these "co-benefits," the SCAQMD has successfully partnered with the state and federally funded projects that promise emission reductions.

Program and Funding Scope

This 2018 Plan Update includes projects to develop, demonstrate and commercialize a variety of technologies, from near-term to long-term, that are intended to address the increasing challenges this region is facing to meet air quality standards, including:

1) implementation of new and changing federal requirements, such as the 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 ready technologies; and
3) continued development of cost-effective approaches.

The overall scope of projects in the 2018 Plan Update also needs to remain sufficiently flexible to address new challenges and measures that are identified in the 2016 AQMP, consider dynamically

[7] 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

evolving technologies, and take into account new research and data. The latter, for example, might include initial findings from MATES V and models generated using EMFAC 2017.

The Clean Air Act, in addition to providing for specific control measures based on known technologies and control methods, has provisions for more general measures based on future, yet-to-be-developed technologies. These "black box" measures are identified under Section 182(e)(5) of the Clean Air Act for regions that are extreme non-attainment areas, such as the South Coast Basin. In the past, some of the technologies that have been developed and demonstrated in the Clean Fuels Program may have served as guidance for the "black box." However, as noted above, the 2016 AQMP calls for elimination on the reliance of these "black box" (future technologies) to the maximum extent possible.

Within the core technology areas defined later in this section, project objectives range from near-term to long-term. However, the SCAQMD 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 Program's projects is described below, from near-term to longer-term.

- *Deployment* or technology commercialization efforts focus on increasing the utilization of clean technologies in conventional applications, promising immediate and growing emissions reduction benefits. It is often difficult to transition users to a non-traditional technology or fuel due to higher costs or required changes to user behaviors, even if such a technology or fuel offers significant societal benefits. As a result, in addition to government's role to reduce risk by funding technology development and testing, one of government's roles is to support and offset any incremental cost through incentives to help accelerate the transition and use of the cleaner technology. The increased use and proliferation of these cleaner technologies often depends on this initial support and funding as well as efforts intended to increase confidence of stakeholders that these technologies are real, cost-effective in the long term and will remain applicable.
- Technologies ready to begin field *demonstration* in 2018, are expected to result in a commercial product in the 2021-2023 timeframe, and technologies being field demonstrated generally are in the process of being certified. The field demonstrations provide a controlled environment for manufacturers to gain real-world experience and address any end-user issues that may arise prior to the commercial introduction of the technology. Field demonstrations provide real-world evidence of a technology's performance to help allay any concerns by potential early adopters.
- Finally, successful technology *development* projects are expected to begin during 2018 with durations of at least two or more years. Additionally, field demonstrations to gain longer-term verification of performance may also be needed prior to commercialization. Certification and ultimate commercialization would be expected to follow. Thus, development projects identified in this plan may result in technologies ready for commercial introduction as soon as 2022-2024. Projects are also proposed that may involve the development of emerging technologies that are considered longer term and, perhaps higher risk, but with significant emission reduction potential. Commercial introduction of such long-term technologies would not be expected until 2025 or later.

Core Technologies

The following technologies have been identified as having the largest potential and best prospects to enable the emission reductions need to achieve NAAQS and thus form the core of the Program.

Not all project categories will be funded in 2018 due to funding limitations, and focus will remain on control measures identified in the 2016 AQMP, with consideration for availability of suitable projects. The technical areas 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 SCAQMD to leverage its funds with other funding agencies to expedite the implementation of cleaner alternative technologies in the Basin. A concerted effort is continually made to form private partnerships to leverage Clean Fuels funds. For example, in January 2016, the SCAQMD was awarded $23.5 million from CARB's Low Carbon Transportation Greenhouse Gas Emission Reduction Fund for heavy-duty truck projects. In 2018, SCAQMD hopes to participate in a CARB-funded zero and near-zero emissions freight facilities project using FY 2017-18 monies their Board has dedicated to clean transportation incentives.

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. The core hybrid electric technologies overlap with each other.

Priorities may shift during the year in keeping with the diverse and flexible "technology portfolio" approach. Priorities may also shift to address specific technology issues which affect residents within the SCAQMD's jurisdiction. Changes in priority may also occur to leverage opportunities such as cost-sharing by the state government, the federal government or other entities.

The following nine core technology areas are listed by current SCAQMD priorities based on the goals for 2018.

Hydrogen & Fuel Cell Technologies & Infrastructure

The SCAQMD supports hydrogen infrastructure and fuel cell technologies as one option in our technology portfolio and is dedicated to assisting federal and state government programs to deploy light-duty fuel cell vehicles (FCVs) by supporting the required refueling infrastructure.

Calendar Years 2015-2018 have been a critical timeframe for the introduction of hydrogen fueling infrastructure. In 2014, Hyundai introduced the Tucson FCV for lease; in 2015, Toyota commercialized the first FCV available to consumers for purchase; and in December 2016, Honda started delivering its 2017 Honda Clarity Fuel Cell. Other OEMS have similarly disclosed plans to introduce FCVs in 2018 and beyond. Since hydrogen refueling stations need 18-36 month lead times for permitting, construction and commissioning, plans for stations need to be implemented now. While coordination efforts 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 to general consumers are still needed. In addition, SCAQMD continues to review the market to understand new business models and new sources of funding besides grants for construction necessary to enable the station operations to remain solvent during the early years until vehicle numbers ramp up. Lastly, a deliberate and coordinated effort is necessary to ensure that the retail hydrogen stations are developed with design flexibility to address specific location limitations, and with refueling reliability matching those of existing gasoline and diesel fueling stations.

Fuel cells can also play a role in medium- and heavy-duty applications where battery capacity is insufficient to meet range requirements. The California Fuel Cell Partnership's (CaFCP) Medium- and Heavy-Duty Fuel Cell Electric Truck Action Plan completed in October 2016 focuses on Class 4 parcel delivery trucks and Class 8 drayage trucks with infrastructure development and establishes metrics for measuring progress. Toyota Motors has also displayed a Class 8 fuel cell truck with planned demonstrations at Port of Long Beach.

The 2018 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 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 marine applications;
- demonstration of fuel cell vehicles in controlled fleet applications in the Basin;
- development and implementation of strategies with government and industry to build participation 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; and
- coordination with fuel cell vehicle OEMs to develop an understanding of their progress in overcoming the barriers to economically competitive fuel cell vehicles and develop realistic scenarios for their large scale introduction.

Engine Systems

Natural gas engines are experiencing market growth due to the low cost of fuel. In order to achieve the emission reductions required for the South Coast Air Basin, the internal combustion engines (ICEs) used in the heavy-duty sector will require emissions that are 90% lower than the 2010 standards. In 2016, commercialization of the Cummins 8.9L natural gas engine achieving 90% 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 SCAQMD and other project partners achieved certification of the 12-liter natural gas engine. The 11.9L 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. 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. Specifically, these projects are expected to target the following:

- development of ultra-low emission, natural gas engines for heavy-duty vehicles and high horsepower applications;
- 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 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, waste heat recovery, improved exhaust or recirculation systems, and aftertreatment devices; and
- development of cold start technologies for hybrids and diesels where high level emissions occur

The National Highway Traffic Safety Administration's finalized standards to improve fuel efficiency of medium- and heavy-duty vehicles for model year 2018 and beyond should spur further interest by manufacturers to partner on engine system development. The EPA's recent initiation to create a rule for a national low NOx standard for all on highway heavy duty engines will require all manufacturers to participate by 2024.

Electric/Hybrid Technologies & Infrastructure

If the region expects to meet the 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 electrification of transportation technologies on a wide and large scale. With that in mind, the SCAQMD supports projects to address the main concerns regarding cost, battery lifetime, travel range, charging station infrastructure and original equipment manufacturer (OEM) commitment. Integrated transportation

systems can encourage further reduction of emissions by matching the features of electric vehicles (zero emissions, zero start-up emissions, all electric range) to typical consumer demands for mobility 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 today when every month roughly 10,000 new plug-in vehicles are sold or leased in the U.S., and this number may increase significantly with the introduction of vehicles with anticipated 200+ mile ranges, such as the Chevy Bolt for which U.S. sales launched in December 2016 and the more affordable Tesla Model 3 which came out in 2017.

The development and deployment of zero emission goods movement systems remains one of the top priorities for the SCAQMD to support a balanced and sustainable growth in the port complex. The SCAQMD 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 (LACMTA) to identify technologies that could be beneficial to and garner support from all stakeholders. Specific technologies include zero emission trucks (using batteries and/or fuel cells), near-zero emission trucks with all-electric range using wayside power (catenary or roadbed electrification) or with plug-in hybrid powertrains, locomotives with near-zero emissions (e.g., 90% below Tier 4), electric locomotives using battery tender cars and catenary, 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 more economical one than it is today, including a call for a zero and near-zero emissions 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 call for zero emission cargo handling equipment by 2030 and zero emission drayage trucks by 2035. Cummins and Tesla have announced plans to demonstrate zero emission heavy-duty trucks, with future commercial plans for heavy-duty vehicle electrification.

There are now over 11 light-duty PHEVs certified to California's cleanest ATPZEV or TZEV standard and 16 pure battery electric vehicles (BEVs) commercially available in California. All of these vehicles offer the benefits of higher fuel economy and range, as well as lower emissions. Continued advancements in the light-duty arena may have applications for medium- and heavy-duty vehicles.

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

- demonstration of electric and hybrid technologies for cargo container transport operations, e.g., heavy-duty battery electric or plug-in electric drayage trucks with all electric range;
- demonstration of medium-duty electric and hybrid electric vehicles in package delivery operations, e.g., electric walk-in vans with fuel cell or CNG range extender ;
- development and demonstration of CNG hybrid vehicle technology;
- demonstration of niche application battery electric 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 electric vehicles and mass transit, and web-based reservation systems that allow multiple users;
- development of eco-friendly intelligent transportation system (ITS) strategies, optimized load-balancing strategies for cargo freight and market analysis for zero emission heavy-duty trucks;
- demonstration and installation of EV infrastructure to support the electric and hybrid-electric vehicle fleets currently on the roads or soon entering the market, and to reduce cost, improve convenience and integrate with renewable energy and building demand management strategies (e.g., vehicle-to-grid or vehicle-to-building functionality);
- repurpose of EV batteries for other or second third energy storage uses, as well as reusing battery packs and approaches to recycle lithium, cobalt and other metals; and

- development of a methodology to increase 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.

Fueling Infrastructure and Deployment (NG/RNG)

The importance of natural gas, renewable natural gas (RNG) and related refueling infrastructure cannot be overemphasized for the realization of large deployment of alternative fuel technologies. 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 South Coast Air 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 establishes a target to double the energy efficiency in electricity and natural gas end uses by 2030.

Active participation in the development of National Fire Protection Association (NFPA) fire and safety codes and standards, evaluation of the cost and economics of the new fuels, public education and training and emergency response capability are just a few areas of the funded efforts that have helped overcome public resistance to these new technologies. 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.

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 the potential health risks). In fact, studies indicate that smoggy areas 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.

Over the past few years, the SCAQMD has funded emission studies to evaluate the impact of tailpipe emissions of biodiesel and ethanol fueled vehicles mainly focusing on criteria pollutants and greenhouse gas (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. Therefore, a couple of years ago the SCAQMD funded studies to investigate the physical and chemical composition and toxicological potential of tailpipe PM emissions from biodiesel and ethanol fueled vehicles to better understand their impact on public health. Studies continued in 2015 to further investigate the toxicological potential of emissions, such as ultrafine particles and vapor phase substances, and to determine whether or not other 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% of all vehicle sales in the U.S. in 2009 to 38% in 2014, with an expectation to top 60% by 2016, it is important to understand the impact on air quality from these vehicles. As such, SCAQMD 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, SCAQMD initiated an in-use real-world emissions study, including fuel usage profile characterization as well as an assessment of the impact of current technology and alternative fuels on fuel consumption.

In recent years, there has also been an increased interest both at the state and national level on the use of alternative fuels including biofuels 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.

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 PEVs on local air quality as well as the benefit of telematics on emissions reduction strategies;
- lifecycle energy and emissions analyses to evaluate conventional and alternative fuels; and
- analysis of fleet composition and its associated impacts on criteria pollutants.

Stationary Clean Fuel Technologies

Although stationary source emissions are small compared to mobile sources in the South Coast Air Basin, there are applications where cleaner fuel technology can be applied to reduce NOx, VOC and PM emissions. For example, a recent demonstration project funded in part by the SCAQMD 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 could be applied to not only improve air quality, but enhance power quality and reduce electricity distribution congestion.

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. The University of California (U.C.) Riverside's Sustainable Integrated Grid Initiative and U.C. Irvine's Advanced Energy and Power Program, funded in part by the SCAQMD, 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., low NOx burners, fuel cells or microturbines);
- exploration of renewables as a source 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.

Emission Control Technologies

Although engine technology and engine systems research is required to reduce the emissions at the combustion source, dual fuel technologies and post-combustion cleanup methods are also needed to address the current installed base of 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. 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 diesel particulate traps and selective catalytic reduction catalysts); and non-thermal regen technology
- development and demonstration of low-VOC and PM lubricants for diesel and natural gas engines.

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 fuels technologies, coordination of these activities with other organizations and information dissemination to educate the end user. Technology transfer efforts include support for various clean fuel vehicle incentive programs as well.

Target Allocations to Core Technology Areas

Figure 48 below presents the potential allocation of available funding, based on SCAQMD projected program costs of $16.7 million for all potential projects. The expected actual project expenditures for 2018 will be less than the total SCAQMD 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 SCAQMD funding. Specific contract awards throughout 2018 will be based on this proposed

allocation, the quality of proposals received and evaluation of projects against standardized criteria and ultimately SCAQMD Governing Board approval.

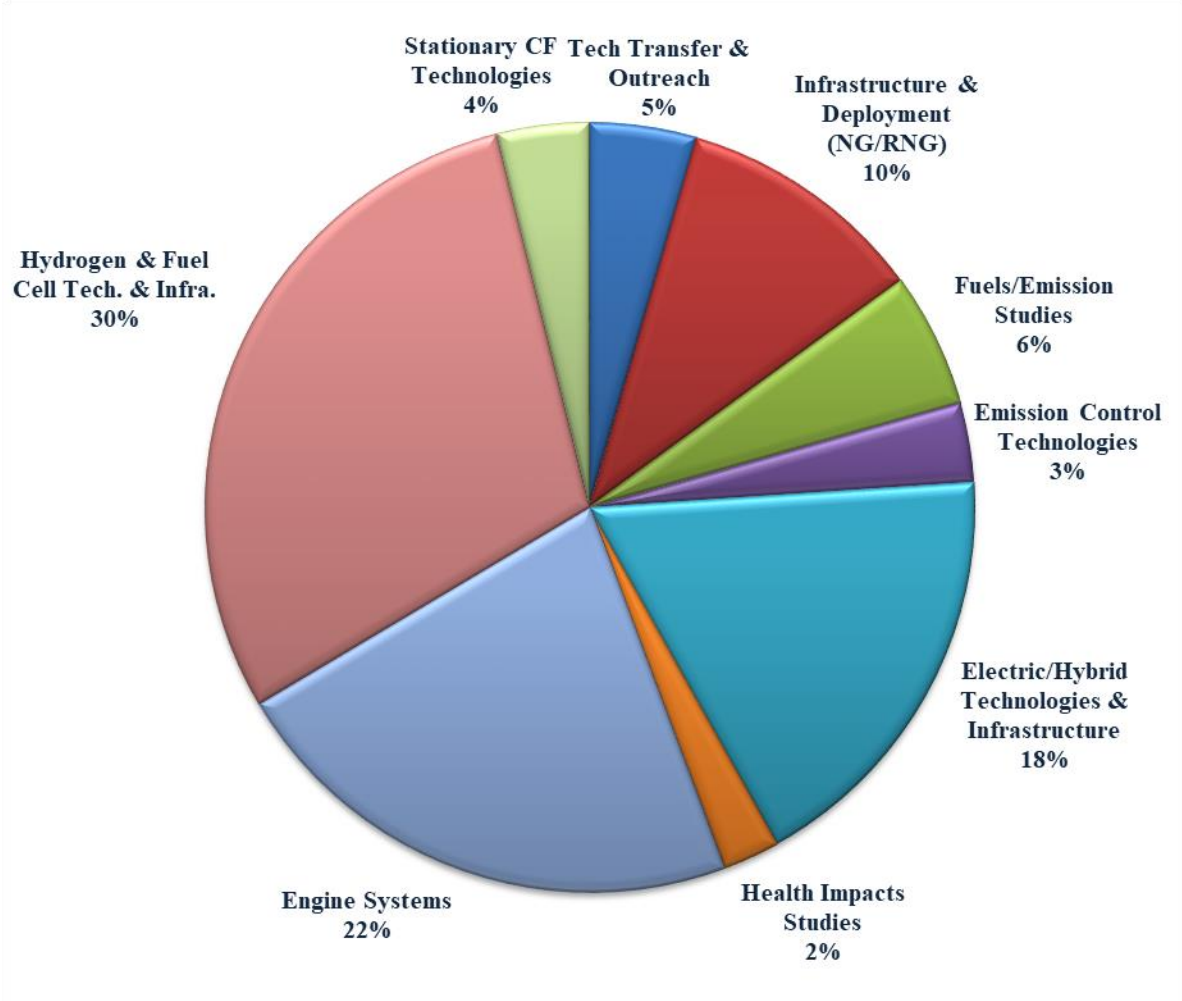


Figure 48: Projected Cost Distribution for Potential SCAQMD Projects in 2018 ($16.7M)

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CLEAN FUELS PROGRAM
Program Plan Update for 2018

This section presents the Clean Fuels Program Plan Update for 2018. The proposed projects are organized by program areas and described in further detail, consistent with the SCAQMD 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 6 (page 89) summarizes potential projects for 2018 as well as the distribution of SCAQMD costs in some areas as compared to 2017. The funding allocation continues the focus on development and demonstration of zero and near-zero emission technologies including the infrastructure for such technologies. For the 2018 Draft Plan, the SCAQMD shifts some resources onto hydrogen and fuel cell technologies to incentivize large-scale hydrogen infrastructure projects at the Ports and in the Inland Empire and in light of current and projected roll out of fuel cell vehicles in 2016-2018. There is a small decrease in electric and hybrid-electric technologies in light of the large award the SCAQMD received in early January 2016 from the GGRF Program to demonstrate vehicles in this technology area. A small funding shift to Engine Systems and Fueling Infrastructure and Deployment (natural gas and renewable fuels) is also recommended for biogas production and to ensure continued development and deployment of near-zero natural gas engines and liquid-fueled high horsepower engines for long-haul trucks. The other areas will continue with similar allocations for 2018. As in prior years, the funding allocations again align well with the SCAQMD's FY 2017-18 Goals and Priority Objectives. Overall, the Program is designed to ensure a broad portfolio of technologies and leverage 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 SCAQMD Governing Board for approval prior to contract initiation. This development reflects the maturity of the proposed technology and identifies contractors to perform the projects, participating host sites, and securing sufficient cost-sharing needed to complete the project and other necessary factors. Recommendations to the SCAQMD Governing Board will include descriptions of the technology to be demonstrated and in what application, the proposed scope of work of the project and the capabilities of the selected contractor and project team, in addition to the expected costs and expected 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 6 (page 89).

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

Expected SCAQMD Cost: The estimated proposed SCAQMD cost share as required by H&SC 40448.5.1.(a)(1).

Expected Total Cost: The estimated total project cost including the SCAQMD 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 SCAQMD 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 6: Summary of Potential Projects for 2018

Proposed Project	Expected SCAQMD Cost $	Expected Total Cost $
Hydrogen and Fuel Cell Technologies and Infrastructure		
Develop and Demonstrate Operation and Maintenance Business Case Strategies for Hydrogen Stations	350,000	4,000,000
Develop and Demonstrate Hydrogen Production and Fueling Stations	2,000,000	6,000,000
Develop and Demonstrate Medium- and Heavy-Duty Fuel Cell Vehicles	2,500,000	10,000,000
Demonstrate Light-Duty Fuel Cell Vehicles	100,000	100,000
Subtotal	$4,950,000	$20,100,000
Engine Systems/Technologies		
Develop and Demonstrate Advanced Gaseous- and Liquid-Fueled Medium- and Heavy-Duty Engines and Vehicle Technologies to Achieve Ultra-Low Emissions	3,000,000	5,600,000
Develop and Demonstrate Alternative Fuel and Clean Conventional Fueled Light-Duty Vehicles	200,000	1,500,000
Develop and Demonstrate Cold-Start Technologies	250,000	1,000,000
Develop and Demonstrate Waste-Heat Recovery on Heavy-Duty Diesel Engines	250,000	1,000,000
Subtotal	$3,700,000	$9,100,000
Electric/Hybrid Technologies & Infrastructure		
Develop and Demonstrate Electric and Hybrid Vehicles	1,000,000	2,000,000
Develop and Demonstrate Infrastructure for Deployment of Plug-in Electric and Hybrid Electric Vehicles	500,000	3,000,000
Demonstrate Alternative Energy Storage	300,000	2,000,000
Develop and Demonstrate Electric Container Transport Technologies	1,200,000	4,000,000
Subtotal	$3,000,000	$11,000,000
Fueling Infrastructure and Deployment (NG/RNG)		
Deploy Natural Gas Vehicles in Various Applications	500,000	2,000,000
Develop, Maintain & Expand Natural Gas Infrastructure	250,000	1,500,000
Demonstrate Natural Gas Manufacturing and Distribution Technologies Including Renewables	1,000,000	10,000,000
Subtotal	$1,750,000	$13,500,000
Fuel/Emissions Studies		
Conduct In-Use Emissions Studies for Advanced Technology Vehicle Demonstrations	400,000	800,000
Conduct Emissions Studies on Biofuels and Alternative Fuels	300,000	1,000,000

Table 6: Summary of Potential Projects for 2018(cont'd)

Proposed Project	Expected SCAQMD Cost $	Expected Total Cost $
Fuel/Emissions Studies (cont'd)		
Identify and Demonstrate In-Use Fleet Emissions Reduction Technologies & Opportunities	250,000	2,000,000
Subtotal	$950,000	$3,800,000
Stationary Clean Fuel Technologies		
Develop and Demonstrate Reliable, Advanced Emission Control Technologies, and Low Emission Monitoring Systems and Test Methods	100,000	250,000
Develop and Demonstrate Clean Stationary Technologies	250,000	750,000
Develop and Demonstrate Renewables-Based Energy Generation Alternatives	300,000	1,000,000
Subtotal	$650,000	$2,000,000
Emission Control Technologies		
Develop and Demonstrate Advanced Aftertreatment Technologies	300,000	5,000,000
Demonstrate On-Road Technologies in Off-Road and Retrofit Applications	250,000	1,000,000
Subtotal	$550,000	$6,000,000
Health Impacts Studies		
Evaluate Ultrafine Particle Health Effects	100,000	2,000,000
Conduct Monitoring to Assess Environmental Impacts	150,000	500,000
Assess Sources and Health Impacts of Particulate Matter	150,000	300,000
Subtotal	$400,000	$2,800,000
Technology Assessment & Transfer/Outreach		
Assess and Support Advanced Technologies and Disseminate Information	425,000	800,000
Support Implementation of Various Clean Fuels Vehicle Incentive Programs	325,000	400,000
Subtotal	$750,000	$1,200,000
TOTALS FOR POTENTIAL PROJECTS	**$16,700,000**	**$69,500,000**

Technical Summaries of Potential Projects

Hydrogen and Fuel Cell Technologies & Infrastructure

Proposed Project: Develop and Demonstrate Operation and Maintenance Business Case Strategies for Hydrogen Stations

Expected SCAQMD Cost: $350,000

Expected Total Cost: $4,000,000

Description of Technology and Application:

California regulations require automakers to place increasing numbers of zero emission vehicles into service every year. By 2050, CARB projects that 87% of light-duty vehicles on the road will be zero emission battery and fuel cell vehicles with fuel cell electric becoming the dominant powertrain.

In 2013, cash-flow analysis resulting in a Hydrogen Network Investment Plan and fuel cell vehicle development partnership announcements by major automakers enabled the passage of AB 8 which provides $20 million per year for hydrogen infrastructure cofunding through the CEC. This resulted in fuel cell vehicle production announcements by Hyundai, Toyota and Honda in 2014-2015.

In October 2016, the CaFCP released its Medium- and Heavy-Duty Fuel Cell Electric Truck Action Plan focusing on Class 4 parcel delivery trucks and Class 8 drayage trucks with infrastructure development and establishing metrics for measuring progress. Additionally, the CaFCP released a Vision 2030 document establishing a roadmap for future fuel cell vehicle and hydrogen refueling stations, including barriers that need to be overcome.

In 2015, Hyundai and Toyota introduced fuel cell vehicles, with Honda initiating delivery in 2016 and others following in 2017 or soon thereafter. Government actions over the last couple of years, coupled with early adopter response, is helping to establish demand and thus a business case model for hydrogen stations.

Additional work in this project category includes (1) developing a plan to secure long-term funding to complete the hydrogen fueling network build-out; (2) providing details how funding can be invested; (3) assessing alternative revenue streams such as renewable incentives; (4) proposing alternative financing structures to leverage/extend CEC funding; and (5) supporting station operation during the transition to commercial viability, including optimizing designs with flexibility to address individual site characteristics, as well as ensuring higher levels of dispensing availability and reliability.

Furthermore, in the next couple of years an evaluation of actual market penetration of FCVs should be conducted to guide and protect local and state investments in the hydrogen market.

Potential Air Quality Benefits:

The 2016 AQMP identifies the use of alternative fuels and zero emission transportation technologies as necessary to meet federal air quality standards. One of the major advantages of Fuel Cell vehicles (FCEVs) 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 FCEVs are available now. The deployment of large numbers of FCEVs, which is an important strategy to attain air quality goals, requires a well-planned and robust hydrogen fueling infrastructure. This SCAQMD project, with significant additional funding from other governmental and private entities, will provide the hydrogen fueling infrastructure that is necessary in the South Coast Air Basin. The deployment of FCEVs and the development of the necessary fueling infrastructure

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

Expected SCAQMD Cost: $2,000,000

Expected Total Cost: $6,000,000

Description of Technology and Application:

Alternative fuels, such as hydrogen and the use of advanced technologies, such as fuel cell vehicles, 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 major challenge to the entry and acceptance of direct-hydrogen fuel cell vehicles is the limited number of hydrogen refueling 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 increased dispensing pressure of 10,000 psi and compatibility with existing CNG stations may be considered.
Energy Stations: Multiple-use energy stations that can produce hydrogen for fuel cell vehicles 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).

Home Refueling Appliances: Home refueling/recharging is an attractive advancement for alternative clean fuels due to the limited conventional refueling infrastructure. This project would evaluate a hydrogen home refueler for cost, compactness, performance, durability, emission characteristics, ease of assembly and disassembly, maintenance and operations. Other issues such as building permits, building code compliance and UL ratings for safety would also be evaluated.

It is estimated that approximately 13,400 fuel cell vehicles will be deployed by 2020 in California and the majority of these vehicles will be in the South Coast Air Basin. To provide fuel for these vehicles, the hydrogen fueling infrastructure needs to be significantly increased and become more reliable in terms of availability. SCAQMD will seek additional funding from CEC and CARB to construct and operate hydrogen fueling stations.

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 SCAQMD 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. Fuel cell vehicles constitute some of the cleanest alternative-fuel vehicles today. Since hydrogen is a key fuel for fuel cell vehicles, 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 SCAQMD Cost: $2,500,000

Expected Total Cost: $10,000,000

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 being mentioned by battery experts as a way of reducing costs and enhancing performance of fuel cell vehicles.

The California ZEV Action Plan specifies actions to help deploy an increasing number of zero emission vehicles, including medium- and heavy-duty ZEVs. 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 fuel cell vehicles 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 SCAQMD funds to demonstrate Zero Emission Container Transport (ZECT) technologies. In 2015, the DOE awarded SCAQMD additional funds to develop and demonstrate additional fuel cell truck platforms and vehicles under ZECT II.

This category may include projects in the following applications:

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

Potential Air Quality Benefits:

The 2016 AQMP identifies the need to implement zero emission vehicles. SCAQMD 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 fuel cell vehicles. 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 zero emission fuel cell vehicles 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.

Proposed Project: Demonstrate Light-Duty Fuel Cell Vehicles
Expected SCAQMD 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 fuel cell passenger vehicles using gaseous hydrogen with proton exchange membrane (PEM) fuel cell technology, mainly through showcasing this technology. Recent designs of light-duty fuel cell vehicles 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 fuel cell limited-production vehicles are planned for retail deployment in early commercial markets near hydrogen stations by several automakers. 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. SCAQMD has included fuel cell vehicles as part of its demonstration fleet since our first hydrogen station began operation in 2005; strengthening support, education, and outreach regarding fuel cell vehicle technology on an on-going 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.

Recently, Hyundai, Toyota and Honda have commercialized fuel cell vehicles in California. Mercedes-Benz announced its pre-production of GLC F-Cell plug-in fuel cell model to be introduced at the end of 2019. Hyundai also has announced its Next-Generation Fuel Cell SUV, which it plans to introduce sometime in 2018. Innovative strategies and demonstration of dual fuel, zero emission vehicles could expand the acceptance of battery electric vehicles and accelerate the introduction of fuel cells in vehicle propulsion.

Potential Air Quality Benefits:

The 2016 AQMP identifies the need to implement zero emission vehicles. SCAQMD 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 fuel cell vehicles. Expected immediate benefits include the deployment of zero-emission vehicles in SCAQMD's demonstration fleet. Over the longer term, the proposed projects could help foster wide-scale implementation of zero emission fuel cell vehicles 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 SCAQMD Cost: $3,000,000

Expected Total Cost: $5,600,000

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 and integration and demonstration of these technologies in on-road vehicles. The NOx emissions target for this project area is 0.02 g/bhp-hr and lower and the PM emissions target is below 0.01 g/bhp-hr. To achieve these targets, an effective emission control strategy must employ advanced fuel system and engine design features, 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 applications;
- development of durable and reliable retrofit technologies to partially or fully convert engines and vehicles from petroleum fuels to alternative fuels; and
- 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, emulsified diesel, dimethyl ether and gas-to-liquid fuels. The project proposes to expand field demonstration of these advanced technologies in various vehicle fleets operating with different classes of vehicles.

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 horsepower engines. Higher horsepower 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 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 in California, both in the Basin and in intrastate operation. The emission reduction benefit 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 engine using natural gas and achieving NOx emissions of 0.02 g/bhp-hr has been certified and commercialized, with larger displacement engines expected to be certified in early 2018. 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 SCAQMD fleet regulations and towards implementation of the 2016 AQMP control measures.

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

Expected SCAQMD Cost: $200,000

Expected Total Cost: $1,500,000

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, bio-diesel 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 SCAQMD 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 Cold-Start Technologies

Expected SCAQMD Cost: $250,000

Expected Total Cost: $1,000,000

Description of Technology and Application:

Cold start of internal combustion engines has negative impacts on the environment. The thermal efficiency of the internal combustion engine is significantly lower at cold-start than when the engine reaches steady state temperatures. If an engine can start at optimal lubricant and component temperatures, an increase in fuel economy and reduction in emissions should be achievable. Diesel engines at cold start increase emissions as much as 10%. 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 their intended operating temperature range as soon as possible after engine start. In most cases, the lubrication system is the primary target of concern. Lubricant viscosity is highly sensitive to temperature and viscosity increases at low temperatures resulting in higher frictional and pumping losses than would be observed at the target operating temperature. This technology should no longer be looked at as "Seasonal". If the oil temperature can increase at start-up, the greatest benefit may be achieved Further benefits can include, but not be limited to, adaptation of algorithms associated with EGR fraction, air preheaters, SCR and fueling requirements. Emissions reductions can be gained and fuel economy improved. This project is to investigate technology to improve oil temperature at start-up 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. The following items are the most recently developed best practices with respect to cost and functionality. Emphasis should be on steady temperature control at start up at optimal degrees already proven and established through significant research.

- Design and prove a battery assisted electric oil heater to maintain a specified temperature continuously before start-up
- Design a lubricant flow system directly from engine head to oil pump to achieve oil temperature more quickly.

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

Potential Air Quality Benefits:

The technology to reduce emissions at cold starts is beneficial to a broad spectrum of vehicles from hybrid electric, light duty to heavy duty engines in long haul trucks. The advancement in this technology will directly contribute toward the ultra-low NOx reductions soon to be required by manufacturers through a national EPA air quality 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 Waste-Heat Recovery in Heavy-Duty Diesel Engines

Expected SCAQMD Cost: $250,000

Expected Total Cost: $1,000,000

Description of Technology and Application:

The objective of this project is to support the demonstration and integration of Waste Heat Recovery (WHR) using the Rankine cycle for on road heavy-duty vehicles. Current WHR programs are showing reductions in GHG of 9-15 % and a 4-5% reduction in fuel consumption in long haul trucking. Diesel engines for heavy-duty commercial vehicles (HCV) convert on average approximately 40% of the primary energy into mechanical power. The residual part is released to the environment. The heat of the exhaust gas can be converted into mechanical power for the vehicle by applying a thermodynamic process. A suitable process is the Rankine process. Research on organic Rankine processes for waste heat utilization in the industry is already being reported as a successful approach. Due to the low oil prices three decades ago, these approaches were not implemented. Today, waste heat recovery can be an attractive approach to reduce fuel consumption and operating costs. Additionally emissions can be lowered 9-15% accordingly. This project is expected to demonstrate in use results in:

- Exhaust gas based recovery systems
- Coolant based recovery systems

A typical Rankine Cycle is a thermodynamic cycle that uses an environmentally friendly organic working fluid such as R134a and works through four reversible processes. In transportation, Rankine cycle systems vaporize a pressurized fluid coming from a steam generator located in the exhaust pipe or from the engine coolant. As a result of the heating, the fluid is turned into steam/vapor. The pressure will then drive the expander of the Rankine engine, which could be a turbine as well as a volumetric expander and that high efficiencies can be achieved at practical operating pressures. The mechanical energy generated by the Rankine process can be delivered to the engine either directly or via a belt transmission. Compared to an electrical utilization concept the mechanical usage shows the advantage of lower energy conversion losses. A belt transmission has the advantage of reducing oscillations. In case of an expansion machine directly coupled with the engine, significant effort is necessary to dampen unfavorable oscillations. The development on going by leading manufacturers in the industry shows great potential for further research and cost saving with the use of cost saving materials such as plastics and aluminum.

Potential Air Quality Benefits:

This project is expected to contribute to the total emissions reductions in heavy-duty on road engines. Emission reduction of 9-15 % in heavy-duty diesel long haul trucks has already been proven when the Rankine cycle is used. This technology can add to the total reduction in emissions in order to meet the ultra-low NOx air quality standards. The fuel savings benefit is especially attractive to long haul fleet operations.

Electric/Hybrid Technologies & Infrastructure

Proposed Project: Develop and Demonstrate Electric and Hybrid Vehicles

Expected SCAQMD Cost: $1,000,000

Expected Total Cost: $2,000,000

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. In the United States, the EPA estimated that in 2015, transportation was responsible for about 28% of the nation's carbon emissions, second only to power plants at 31%.

The global light-duty vehicle market is changing rapidly in response to government-led initiatives to improve fuel economy and market demand for alternative transportation options. These changes are being driven primarily by the adoption of vehicles with various levels of drivetrain electrification. The SCAQMD has long supported the concept of using increased battery power to allow a portion of the driving cycle to occur in all-electric mode for true zero emission miles. This battery dominant strategy is accomplished by incorporating an advanced battery pack initially recharged from the household grid or EV chargers. This "plug-in" hybrid EV strategy allows reduced emissions and improved fuel economy. In 2009, CARB adopted Plug-In Hybrid Electric Vehicle Test Procedure Amendments and Aftermarket Parts Certification. Most automobile manufacturers have announced production plans for a range of electrified vehicle powertrains, including "blended" plug-in hybrid electric, extended-range electric vehicles (E-rEV), or battery electric vehicles (BEVs). Electric utilities refer to PHEVs, E-rEVs and BEVs as plug-in electric drive vehicles (PEVs) and are working with automakers to support PEVs. Long-range BEVs are now becoming price competitive after subsidies and affordable 200+ mile BEVs should have a big impact on the vehicle market. Plug-in hybrids (PHEVs) are also making significant advances. Continued market expansion is likely to result from expanding OEM applications of the powertrain in new, larger vehicle body types, and most large OEMs have made statements regarding a path towards electrification of their vehicle models.

The SCAQMD 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 SCAQMD will continue to evaluate market offerings and proposed technologies in light-duty vehicles to determine if any future support is required.

Medium- and heavy-trucks make up 4.3% of vehicles in the United States and drive 9.3% of all miles driven each year, yet are responsible for more than 25% of all the fuel burned annually. 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 are where most emissions reductions are required, especially for the in-use fleet due to low turnover.

CARB's Low Carbon Transportation programs, local support and federal funds have collectively accelerated the development and demonstration of medium-duty plug-in hybrid electric truck platforms. Analysis of project data and use profiles will help optimize drive systems, target applications for early commercialization and fill gaps in product offerings.

The SCAQMD has investigated the use of hybrid technologies to achieve similar performance as the conventional-fueled counterparts while achieving both reduced emissions and improved fuel economy. Development and validation of emission test procedures is needed, but is complicated due to the low volume and variety of medium- and heavy-duty vehicles.

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; battery-dominant hybrid systems utilizing off-peak re-charging, with advanced battery technologies such as lithium-ion; and hydraulic energy storage technologies where applicable. 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, clean diesel, or even biodiesel may be considered if the emissions benefits can be demonstrated as equivalent or superior to alternative fuels. Both new designs and retrofit technologies and related charging infrastructure will be considered.

This project category is to develop and demonstrate:

- various PEV architectures;
- anticipated costs for such architectures;
- customer interest and preferences for each alternative;
- integration of the technologies into prototype vehicles and fleets;
- evaluation of any new promising light-duty vehicle propulsion technologies or fuels; and
- 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)

Potential Air Quality Benefits:

The 2016 AQMP identifies zero or near-zero emitting vehicles as a key attainment strategy. Plug-in HEV technologies have the potential to achieve near-zero emissions 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 PEV 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 near-ZEV and ZEV technologies.

Expected benefits include the establishment of criteria for emissions 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 emitting vehicles in the South Coast Basin, which is a high priority of the AQMP.

Proposed Project: Develop and Demonstrate Infrastructure for Deployment of Plug-in Electric and Hybrid Electric Vehicles

Expected SCAQMD Cost: $500,000

Expected Total Cost: $3,000,000

Description of Technology and Application:

There is a critical need to address gaps in EV charging infrastructure which has resulted in a deficiency of public EV charging infrastructure availability. Almost half (48%) of the 679,592 EVs sold in the U.S. since 2011 were in California, and of those sales in California, it is estimated that almost half (43%) received CA rebate incentives in SCAQMD. In addition, the California ZEV Action Plan, which was updated in 2016, calls for 1.5 million ZEVs by 2025, calling for an increase of about 200,000 ZEVs annually between now and 2025.

The recent adoption of revised recommended practice SAE J1772 enables passenger vehicles to charge from 110/120V AC (Level 1), 220/240V AC (Level 2), and faster 440/480V DC charging using a common conductive connector in 30 minutes or less in the U.S. and Europe. Together with the growing adoption of long range EVs, the technology and infrastructure of three fast DC charging systems (SAE combo, CHAdeMO and Tesla) are developing as well. 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. SCAQMD 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 and the Volkswagen Penalty Fund.

The SCAQMD is actively pursuing development of intelligent transportation systems to improve traffic efficiency of electric and hybrid cargo container trucks. This system provides truck drivers real-time vehicle operation advice based on changing traffic and road conditions where trucks can dynamically change their speed to better flow through intersections. A truck eco-routing system can provide the most eco-friendly 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 SCAQMD's continued efforts to:

- deploy a network of DC fast charging infrastructure and rapidly expand the existing network of public plug-in EV charging stations;
- support investigation of fast-charging impact on battery life;
- develop intelligent transportation system strategies for cargo containers;
- develop freight load-balancing strategies as well as to conduct market analysis for zero emission heavy-duty trucks in goods movement; and
- support for local government outreach and charging installation permit streamlining.

Potential Air Quality Benefits:

The 2016 AQMP identifies zero or near-zero emitting vehicles as a key attainment strategy. Hybrid technologies have the potential to redirect previously wasted kinetic energy into useable vehicle power. This proposed project category will reduce Particulate Matter (PM) pollution along major roadways through the expansion of the public plug-in EV charging infrastructure network by allowing drivers to

shift away from petroleum-fueled vehicles to plug-in EVs. 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 emissions evaluations, performance requirements and customer acceptability of the technology. This will help both regulatory agencies and OEMs to expedite introduction of near-zero emitting vehicles in the South Coast Basin, which is a high priority of the AQMP.

Proposed Project: Demonstrate Alternative Energy Storage

Expected SCAQMD Cost: $300,000

Expected Total Cost: $2,000,000

Description of Technology and Application:

The SCAQMD 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, including nickel sodium chloride, lithium-ion and lithium iron phosphate 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 cheaper 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 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: Develop and Demonstrate Electric Container Transport Technologies

Expected SCAQMD Cost: $1,200,000

Expected Total Cost: $4,000,000

Description of Technology and Application:

Advanced transportation systems can be used to transfer cargo containers from ports to both local and "distant" intermodal facilities, thereby significantly reducing emissions from on-road trucks and locomotives and also reducing traffic congestion in local transportation corridors. Such systems could be stand-alone systems that use magnetic levitation (maglev), linear synchronous motors or linear induction motors on dedicated guideways. A more near-term design could use existing roadways that are electrified with catenary electric lines or linear electric motors to move containers on modified trucks equipped to run on electricity. In both scenarios, containers are transported relatively quietly and without direct emissions. The footprints for such systems are similar to conventional rail systems but have reduced impact on adjacent property owners including noise and fugitive dust. These systems can even be built above or adjacent to freeways or on elevated guideways. These container freight systems are not designed to carry any operators on the guideways, where the over-the-roadway system may require the operator to actively control the transport of the containers.

One of the container transportation concepts the SCAQMD is actively pursuing is the eHighway catenary hybrid truck system by Siemens Mobility. Siemens and their partners have developed a catenary system and hybrid electric trucks to utilize the catenary for zero emission transport of containers. The hybrid drive system will extend the operating range of the truck beyond the all-electric range of the catenary system, thus enabling the truck to perform regional drayage operations and bridge gaps in catenary infrastructure as it is deployed on a regional level. The proposed Siemens pantograph system will allow for seamless connection and disconnection from the catenary wires. When entering the catenary system corridor, the pantograph system will verify the presence of catenary lines and allow the driver to raise the pantograph from within the cab of the truck. Upon leaving the catenary system, the pantograph automatically retracts and the truck switches to on-board power systems. The on-board power systems could be a range of technologies, including batteries, fuel cells, or internal combustion engines. In addition, SCAQMD is administering a project to develop and demonstrate zero emission drayage trucks for goods movement operations, consisting of three different battery electric truck technologies and a fuel cell hybrid electric truck platform. This project is funded by a $4.2 million award from Department of Energy to promote the deployment of zero emission cargo transport technologies. These trucks can be also upfitted to connect to wayside power via a catenary or linear synchronous motor (LSM) system in the future. Recently, CARB awarded SCAQMD more than $23 million towards the development, demonstration and deployment of up to 43 trucks for goods movement, either with all electric operation or all electric range within disadvantaged communities. The total project cost is approximately $40 million, with the remainder funds cost-shared between five sister air quality agencies, OEMs and demonstration sites.

In addition to these technologies, there are other options for electric container applications such as dual-mode locomotives, hybrid electric technologies with battery storage, a battery tender car, fuel cell propulsion systems and other wayside power alternatives. This technical review will evaluate all available technology options to determine whether their systems can be successfully developed and deployed, financially viable, and reliably operated on a long-term basis.

Potential Air Quality Benefits:

On-road heavy-duty diesel truck travel is an integral part of operations at the ports moving cargo containers into the Basin and beyond. The 2016 AQMP proposes to reduce emissions from this activity by modernizing the fleet and retrofitting NOx and PM emission controls on older trucks. An alternative approach, especially for local drayage to the nearby intermodal facilities, is to use advanced container

transport systems that use electric propulsion for the containers on fixed guideways or modified trucks able to operate on electricity which will eliminate local diesel truck emissions. The emission benefits have not yet been estimated because the fate of the displaced trucks has not been determined.

Fueling Infrastructure and Deployment (NG/RNG)

Proposed Project: Deploy Natural Gas Vehicles in Various Applications

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

Expected Total Cost: $2,000,000

Description of Technology and Application:

Natural gas vehicles (NGVs) have been very successful in reducing emissions in the South Coast Air Basin due to the deployment of fleets and heavy-duty vehicles utilizing this clean fuel. In order to maintain the throughput, utility and commercial potential of the natural gas infrastructure and the corresponding clean air benefits, deploying additional models of NGVs in existing applications are needed. This technology category seeks to support the implementation of early-commercial vehicles in a wide variety of applications, such as taxis, law enforcement vehicles, shuttle buses, delivery vans, transit buses, waste haulers, class 8 tractors and off-road equipment such as construction vehicles and yard hostlers. It also seeks to deploy low-emission natural gas vehicles using renewable fuels to achieve further emission reductions.

Potential Air Quality Benefits:

Natural gas vehicles have inherently lower engine criteria pollutant emissions than conventional vehicles, especially in the heavy-duty applications where older diesel engines are being replaced. Incentivizing these vehicles in city fleets, goods movement applications and transit bus routes help to reduce the local emissions and exposure to nearby residents. Natural gas vehicles also can have lower greenhouse gas emissions and increase energy diversity depending on the feedstock and vehicle class. Deployment of additional NGVs is in agreement with SCAQMD's AQMP as well as the state's Alternative Fuels Plan as part of AB 1007 (Pavley).

Proposed Project: Develop, Maintain & Expand Natural Gas Infrastructure

Expected SCAQMD Cost: $250,000

Expected Total Cost: $1,500,000

Description of Technology and Application:

This project supports the development, maintenance and expansion of natural gas fueling station technologies to increase the overall number of such fueling stations in strategic locations throughout the Basin including the Ports. The intent is to develop and demonstrate advanced technologies to reduce the cost of natural gas equipment, develop and demonstrate closed loop systems for dispensing and storage, standardize fueling station design and construction and help with the implementation of SCAQMD's fleet rules. As natural gas fueling equipment begins to age or has been placed in demanding usage, components will deteriorate. This project offers an incentive to 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. NGVs have significantly lower emissions than gasoline vehicles 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, besides improving the refueling time. While new or improved NGV stations have an indirect emissions reduction benefit, they help facilitate the introduction of low emission, NGVs in private and public fleets in the area, which have a direct emissions reduction benefit. 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 Natural Gas Manufacturing and Distribution Technologies Including Renewables

Expected SCAQMD Cost: $1,000,000

Expected Total Cost: $10,000,000

Description of Technology and Application:

Lack of sufficient statewide LNG production results in increased fuel costs and supply constraints. The cost of transporting LNG from out-of-state production facilities increases the fuel cost from 15 to 20 cents per gallon of LNG and subjects users to the reliability of a single supply source. High capital costs prevent construction of local, large-scale liquefaction facilities. Small-scale, distributed LNG liquefaction systems may provide 25 percent lower capital costs than conventional technology per gallon of LNG produced. Because these smaller plants can be sited near fleet customers, costs for transporting the LNG to end-users are much lower than those for remote larger plants. Beyond these cost reductions, the smaller plants offer key benefits of much smaller initial capital investment and wider network of supply than the larger plant model.

The project category will also consider the development and demonstration of technologies for the production of Renewable Natural Gas (RNG) from various feed stocks including landfill gas, green waste, and anaerobic digester gases.

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

- commercially viable methods for converting renewable feed stocks into CNG or LNG (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 LNG and L/CNG refueling facilities; and
- strategic placement of LNG storage capacity sufficient to provide supply to users in the event of a production outage.

Potential Air Quality Benefits:

The SCAQMD relies on a significant increase in the penetration of zero- and low-emission vehicles in the South Coast Basin to attain federal clean air standards by 2014, 2023 and 2032. This project would help develop a number of small-scale liquefaction technologies that can reduce LNG costs to be competitive with diesel fuel. Such advances are expected to lead to greater infrastructure development. This would make LNG fueled heavy-duty vehicles more available to the commercial market leading to direct reductions in NOx, PM and toxic compound emissions.

Fuels/Emission Studies

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

Expected SCAQMD Cost: $400,000

Expected Total Cost: $800,000

Description of Technology and Application:

Hybrid electric, hybrid hydraulic, plug-in electric hybrid and pure EVs will all play a unique 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.

The environmental benefit for each technology class will be highly 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. These positive results 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 SCAQMD's air quality goals.

Proposed Project: Conduct Emissions Studies on Biofuels and Alternative Fuels

Expected SCAQMD Cost: $300,000

Expected Total Cost: $1,000,000

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 on 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 has recently amended the 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.

Furthermore, 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.

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.

Potential Air Quality Benefits:

If 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 SCAQMD 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.

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

Expected SCAQMD Cost: $250,000

Expected Total Cost: $2,000,000

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, marine vessels 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; and
- development, deployment and demonstration of smart vehicle telematic systems

Potential Air Quality Benefits:

Many of the technologies identified can be applied to light-duty 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.

Stationary Clean Fuel Technologies

Proposed Project: Develop and Demonstrate Reliable, Advanced Emission Control Technologies, and Low-Emission Monitoring Systems and Test Methods

Expected SCAQMD Cost: $100,000

Expected Total Cost: $250,000

Description of Technology and Application:

Currently, the inability of air/fuel ratio control (AFRC) systems to keep rich-burn engines in compliance contributes significantly to air pollution in the basin. Reliable, low-cost emission monitoring systems are needed for small-to-intermediate size combustion devices, including stationary engines, boilers, heaters, furnaces and ovens that are not large enough to justify a continuous emission monitoring system (CEMS). This class of combustion device is often permitted on the basis of a single demonstration or periodic demonstrations of NOx and CO emissions meeting SCAQMD rule requirements or a RECLAIM concentration limit. However, SCAQMD-unannounced tests on engines and boilers have found that in many cases NOx and/or CO levels have increased significantly above levels that have been initially or periodically demonstrated due to equipment malfunction and/or inadequate operator attention. It is suspected that the same may be true of heaters, furnaces and ovens.

A recent demonstration project funded in part by the SCAQMD consisted of retrofitting a biogas engine with a digester gas clean up system and catalytic oxidizer at the exhaust followed by SCR which resulted in significant reductions of NO_x, VOC and CO. Based on the successful deployment of this project, further emission reductions may be achieved by other biogas combustion sources such as gas turbines and boilers by the continued development of specialized low cost biogas clean up systems that will allow for the use of catalytic after control systems.

Demonstrations of newer technologies in recent years could result in a commercially viable alternative to CEMS that is both reliable and feasible in terms of lower costs. For example, manufacturers of flue gas analyzers have, in recent years, developed low-cost multi-gas analyzers suitable for portable or stack-mounted use. Some preliminary testing of a new type of AFRC, which uses a different type of O2 sensor known as a wide-band O2 sensor, is another alternative that can be analyzed. Another technical approach might be to deploy technology utilizing the O2 signature of a post-catalyst O2 sensor and additional control concepts being developed by manufacturers. Since an underlying problem has been that engine, catalyst and AFRC manufacturers have developed systems independently, a system being co-developed to perform continuous diagnostics to assist operators in keeping rich-burn engines in compliance is possibly another alternative for demonstration.

Potential Air Quality Benefits:

Stationary engines, boilers, heaters, furnaces and ovens account for approximately 11 percent of total NO_x emissions and about 6 percent of total CO emissions. There has been a long-standing compliance problem with rich-burn IC engines in the basin and evidence indicates that many of these devices are operating with NOx and/or CO emissions above levels required in their permits. 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 SCAQMD's ability to enforce full-time compliance.

Proposed Project: Develop and Demonstrate Clean Stationary Technologies

Expected SCAQMD Cost: $250,000

Expected Total Cost: $750,000

Description of Technology and Application:

Stationary sources, including VOC sources such as large printing facilities and furniture manufacturers, have become cleaner and cleaner due to the regulatory requirements for low emissions and the advancements in technology to meet those requirements. Best Available Control Technology (BACT) regulations, however, are only required for new, modified, or relocated sources. This project category is to develop and demonstrate new technologies that can provide emissions reductions in new installations or as retrofit modifications. Possible technology examples include:

- low NOx technologies (burners and ICEs);
- low-Btu gas technologies (e.g., digester, landfill, or diary gases);
- alternative fuels and hydrogen blends;
- alternative diesel fuels (emulsified, gas-to-liquids, biodiesel with aftertreatment);
- low emission refinery flares;
- catalytic combustion;
- cost-effective fuel cell and fuel cell hybrid distributed generation;
- fumes-to-fuel technology to replace thermal oxidizers and capture VOC emissions for electricity generation while ensuring no emission of air toxics; and
- boiler optimization design and strategies to improve efficiencies.

Depending on the technology, a proof-of-concept project, demonstration, or pre-commercial deployment would be considered to garner further information on the technology. Issues to investigate include viability (reliability, maintainability and durability) of the technology, cost-effectiveness and operator ease-of-use in order to assess commercialization.

Potential Air Quality Benefits:

The SCAQMD has a substantial number of older, small, stationary source technologies within its jurisdiction. Since these devices are not subject to continuous emissions monitoring system requirements, evidence suggests that these devices may not be operating at their permitted NOx, CO, hydrocarbon and PM emissions levels. Replacing these devices with cleaner and more reliable technologies or technology/fuel combinations can have dramatic reductions in all of these criteria pollutants. VOC emission reductions may also be achieved at larger stationary VOC sources to achieve the new federal ozone and PM2.5 standards.

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

Expected SCAQMD Cost: $300,000

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.

Emission Control Technologies

Proposed Project: Develop and Demonstrate Advanced Aftertreatment Technologies

Expected SCAQMD Cost: $300,000

Expected Total Cost: $5,000,000

Description of Technology and Application:

There are a number of aftertreatment technologies which have shown substantial emission reductions in diesel engines. These technologies include diesel particulate filters (DPFs), oxidation catalysts, selective catalytic reduction (SCR) systems and NOx adsorbers. 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 emission 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 diesel engines, street sweepers, waste haulers and transit buses. Applications for non-road may include construction equipment, yard hostlers, gantry cranes, locomotives, marine vessels, 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 SCR and NOx adsorbers, could also have NOx reductions of up to 90%.

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

Expected SCAQMD Cost: $250,000

Expected Total Cost: $1,000,000

Description of Technology and Application:

Heavy-duty on-road 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, marine vessels 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 non-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 SCAQMD Cost: $100,000

Expected Total Cost: $2,000,000

Description of Technology and Application:

Reducing diesel exhaust from vehicles has become a high priority in the South Coast Air 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 this 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 amount 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 SCAQMD Cost: $150,000

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 Particulate Matter

Expected SCAQMD Cost: $150,000

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 South Coast Air 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 South Coast Air 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 regional modeling effort to characterize risk across the Basin. In addition 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.

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 South Coast Air Basin. This information in turn can be used to determine the health benefits of promoting clean fuel technologies.

Technology Assessment and Transfer/Outreach

Proposed Project: Assess and Support Advanced Technologies and Disseminate Information

Expected SCAQMD Cost: $425,000

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 SCAQMD'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;
- advanced technology vehicle demonstrations;
- 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, reports and bulletins; and
- production and dissemination of information, including web sites.

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:

SCAQMD 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 SCAQMD 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 SCAQMD Cost: $325,000

Expected Total Cost: $400,000

Description of Project:

This project supports the implementation of zero emission vehicle incentive programs, the Carl Moyer incentives program and the school bus incentives program. Implementation support includes application approval, grant allocation, documentation to the CARB, verification of vehicle registration 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.

Potential Air Quality Benefits:

As described earlier, the SCAQMD will provide matching funds to implement several key incentives programs to reduce diesel emissions in the Basin. Furthermore, the SCAQMD 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 SCAQMD 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

SCAQMD Advisory Groups

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Technology Advancement Advisory Group

Dr. Matt Miyasato, Chair	SCAQMD
*Don Anair	Non-Governmental Organization
Vacant	California Air Resources Board
*Dr. Sunita Satyapal	Department of Energy
Dr. John Froines	Professor Emeritus University of California, Los Angeles
Gretchen Hardison	Los Angeles Department of Water and Power; Chair of Technical Advisory Committee of the Mobile Source Air Pollution Reduction Review Committee
Dawn Wilson	Southern California Edison
David Pettit	Natural Resources Defense Council
Randall Lewis	Lewis Group of Companies
Tim Olson	California Energy Commission
Nick Economides	Western States Petroleum Association
Cherif Youssef	Southern California Gas Company

*Newly appointed members

SB 98 Clean Fuels Advisory Group

Dr. Matt Miyasato, Chair	SCAQMD
Robert Bienenfeld	American Honda Motor Company Inc.
*Dr. Stephen Charlton	Independent Consultant in Combustion Technology
Dr. Mridul Gautam	West Virginia University, Adjunct Professor, & University of Nevada-Reno
Dr. Fritz Kalhammer	Independent Consultant in Energy and Process Technology
John Faust	California Environmental Protection Agency, Office of Environmental Health Hazard Assessment
Dr. Wayne Miller	University of California, Riverside, College of Engineering, Center for Environmental Research and Technology
Vacant	University of Florida, Professor Emeritus
Dr. Scott Samuelsen	University of California, Irvine, Combustion Laboratory/National Fuel Cell Research Center
Dr. Robert Sawyer	Sawyer Associates
Kevin Walkowicz	National Renewable Energy Laboratory
*Andreas Truckenbrodt	Independent Consultant in Fuel Cell Technologies
Michael Walsh	Independent Consultant in Motor Vehicle Pollution Control

*Newly appointed members

Appendix B

Open Clean Fuels Contracts as of January 1, 2018

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Contract	Contractor	Project Title	Start Term	End Term	SCAQMD $	Project Total $
Hydrogen and Mobile Fuel Cell Technologies and Infrastructure						
11555	University of California Los Angeles	Construct Hydrogen Fueling Infrastructure	12/07/12	12/31/19	400,000	2,589,990
12057	Linde, LLC	Expand Hydrogen Fueling Infrastructure	11/02/12	04/01/19	80,000	160,000
14684	California Department of Food and Agriculture, Division of Measurement Standards	Conduct Hydrogen Station Site Evaluations for Site Certifications for Commercial Sale of Hydrogen	12/11/15	02/28/18	100,000	100,000
15150	Air Products and Chemicals Inc.	Install and Upgrade Eight Hydrogen Fueling Stations Throughout SCAB (including SCAQMD's Diamond Bar Hydrogen Station)	10/10/14	04/09/19	1,000,000	17,335,439
15366	EPC LLC	Operate and Maintain Publicly Accessible Hydrogen Fueling Station at SCAQMD's Headquarters	10/10/14	02/16/18	0	0
15609	ITM Power, Inc.	Installation of Riverside Renewable Hydrogen Fueling Station	10/06/15	10/05/19	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
15641	Hardin Hyundai	Three-Year Lease of 2015 Tucson Fuel Cell Vehicle	06/15/15	06/14/18	22,862	22,862
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
16171	Longo Toyota	Three-Year Lease of 2015 Toyota Mirai Fuel Cell Vehicle	12/15/15	12/14/18	24,567	24,567
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	04/26/18	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

Contract	Contractor	Project Title	Start Term	End Term	SCAQMD $	Project Total $
Hydrogen and Mobile Fuel Cell Technologies and Infrastructure (cont'd)						
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
17394	Energy Independence Now	Provide Analysis of Renewable Hydrogen Pathways, Economics and Incentives	10/20/17	03/19/18	25,000	140,000
Engine Systems & Technologies						
15632	Gas Technology Institute	Develop Ultra Low-Emission Natural Gas Engine for On-Road Medium-Duty Vehicles	09/01/15	06/30/18	750,000	1,800,000
16205	Cummins Westport, Inc.	Develop, Integrate and Demonstrate Ultra-Low Emission 12-Liter Natural Gas Engines for On-Road Heavy-Duty Vehicles	06/03/16	06/30/18	5,250,000	6,250,000
17197	VeRail Technologies Inc.	Develop and Demonstrate Ultra-Low Emission Natural Gas Switcher Locomotive	03/03/17	09/02/19	1,000,000	5,100,000
18018	North American Repower LLC	Develop High Efficiency Near-Zero Emission Natural Gas Engines for Heavy-Duty Vehicles	12/14/17	12/12/19	200,000	1,958,096
Electric/Hybrid Technologies and Infrastructure						
08063	Quantum Fuel Systems Technologies Worldwide, Inc.	Develop & Demonstrate 20 Plug-In Hybrid Electric Vehicles	01/22/08	01/31/18	2,165,613	2,899,057
13058	Capstone Turbine Corporation	Develop Microturbine Series Hybrid System for Class 7 Heavy-Duty Vehicle Applications	08/12/13	12/31/18	360,000	1,210,000
13426	Transportation Power, Inc.	Develop & Demonstrate Catenary Class 8 Trucks (1 Electric & 1 CNG Platform)	06/07/13	07/31/18	2,617,887	3,182,795
13433	U.S. Hybrid Corporation	Develop and Demonstrate Two Class 8 Zero-Emission Electric Trucks	06/26/13	09/30/18	75,000	150,000
13439	City of Carson	MOU for Catenary Zero Emission Goods Movement Project	10/01/13	07/31/18	0	0
14052	Altec Capital Services, LLC	Lease of Two Plug-In Hybrid Electric Vehicles	01/02/15	01/01/20	61,302	61,302
14062	Siemens Industry Inc.	Develop and Demonstrate Catenary Zero Emissions Goods Movement System and Develop and Demonstrate Diesel Catenary Hybrid Electric Trucks	07/14/14	07/13/18	5,500,000	14,780,000
14184	Clean Fuel Connection Inc.	DC Fast Charging Network Provider	04/04/14	06/30/20	920,000	1,220,000

Contract	Contractor	Project Title	Start Term	End Term	SCAQMD $	Project Total $
Electric/Hybrid Technologies and Infrastructure (cont'd)						
14222	Odyne Systems,LLC	Develop and Demonstrate Plug-In Hybrid Electric Retrofit System for Class 6 to 78 Trucks	04/24/14	05/31/18	389,000	2,226,571
14256	National Strategies LLC	Develop and Demonstrate Vehicle-2-Grid Technology	09/05/14	03/04/18	250,000	3,377,689
15382	ChargePoint, Inc.	Install Electric Charging Infrastructure	01/23/15	1/31/18	162,000	162,000
15650	University of California San Diego	Develop and Demonstrate Solar Forecasting for Larger Solar Arrays with Storage and EV Charging	07/17/15	01/16/18	98,908	1,655,278
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	09/30/18	195,326	2,103,446
16047	U.S. Hybrid Corporation	ZECT: Develop and Demonstrate Three Class 8 LNG Plug-In Hybrid Electric Drayage Trucks	11/06/15	09/30/18	22,896	1,996,675
16081	Broadband TelCom Power, Inc.	Provide EV Hardware and Control System at SCAQMD Headquarters including Installation Support, Warranty and Networking	04/27/16	04/26/22	367,425	367,425
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
16227	Selman Chevrolet Company	Lease One 2016 Chevrolet Volt Extended-Range Electric Vehicle for Three Years	02/01/16	01/31/19	15,677	15,677
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

Contract	Contractor	Project Title	Start Term	End Term	SCAQMD $	Project Total $
Fueling Infrastructure and Deployment (NG/RNG)						
09364	Rim of the World Unified School District	Construct & Install a CNG Fueling Station	12/30/10	10/31/18	257,000	425,000
12667	West Covina Unified School District	Upgrade CNG Fueling Facility	10/12/12	03/01/20	60,000	60,000
12851	Clean Energy	Install, Operate and Maintain Three LNG Fueling Stations (Fontana, Coachella and Perris)	10/05/12	12/31/18	1,400,000	4,277,323
12852	City of Covina	Construct Public Access CNG Fueling Stations	10/12/12	12/31/18	200,000	618,429
12853	Rainbow Disposal Co. Inc.	Upgrade CNG Fueling Station	03/08/13	12/31/18	200,000	400,000
12854	Waste Management, Inc.	Upgrade LNG Fueling Station at Baldwin Park Facility	08/17/12	12/31/18	300,000	1,588,100
14219	City of West Covina	Upgrade CNG Station at City Yard	05/15/14	08/01/19	200,000	618,429
15438	United Parcel Service, Inc.	Refurbish/Upgrade Ontario UPS LCNG Infrastructure	12/31/14	06/30/18	246,707	484,535
15541	Foundation for California Community Colleges	Implement Enhanced Fleet Modernization Program	05/07/15	01/30/19	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
16076	Coachella Valley Association of Governments	Purchase and Deploy One Heavy-Duty CNG Paratransit Vehicle	12/01/15	11/20/19	140,000	140,000
16244	CR&R, Inc.	Renewable Natural Gas Production and Vehicle Demonstration Project	09/03/16	03/02/20	900,000	55,000,000
16333	Ontario CNG Station, Inc.	Implement Alternative Fuel Station Expansion	05/13/16	11/12/19	200,000	798,535
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
17349	University of California Riverside/CE-CERT	Establish Renewable Natural Gas Center	08/03/17	08/02/18	100,000	261,110
Fuels/Emission Studies						
15607	University of California Riverside/CE-CERT	Innovative Transportation System Solutions for NOx Reductions in Heavy-Duty Fleets	12/19/15	04/30/18	79,980	139,980
15625	University of California Riverside/CE-CERT	Evaluate SOA Formation Potential from Light-Duty GDI Vehicles	10/02/15	06/30/18	149,972	224,972
15636	University of California Riverside/CE-CERT	Evaluate PEV Utilization Through Advanced Charging Strategies in a Smart Grid System	12/15/15	06/30/18	170,000	270,000

Contract	Contractor	Project Title	Start Term	End Term	SCAQMD $	Project Total $
Fuels/Emission Studies (cont'd)						
15680	National Renewable Energy Laboratory	ComZEV: Develop Detailed Technology and Economics-Based Assessment for Heavy-Duty Advanced Technology Development	08/25/15	06/30/18	520,000	540,000
17060	University of California Riverside	Bailment Agreement for Equipment Use for In-Use Emissions Testing of Heavy-Duty Inspection and Maintenance Program	10/13/16	10/12/18	0	0
17245	West Virginia University Research Corporation	Conduct In-Use Emissions Testing and Fuel Usage Profile on On-Road Heavy-Duty Vehicles	06/09/17	06/08/21	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	11/02/19	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	11/02/19	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	06/08/21	1,625,000	1,625,000
17331	University of California Riverside/CE-CERT	Conduct In-Use PM Emissions Study for Gasoline Direct Injection Vehicles	07/14/17	07/31/18	222,000	273,000
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	12/04/18	85,000	85,000
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 SCAQMD Headquarters	09/28/12	09/27/22	450,000	4,252,680
Technology Assessment/Transfer & Outreach						
08210	Sawyer Associates	Technical Assistance on Mobile Source Control Measures and Future Consultation on TAO Activities	02/22/08	02/28/18	10,000	10,000
09252	JWM Consulting Services	Technical Assistance with Review and Assessment of Advanced Technologies, Heavy-Duty Engines, and Conventional and Alternative Fuels	12/20/08	06/30/18	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	05/31/18	75,000	75,000

Contract	Contractor	Project Title	Start Term	End Term	SCAQMD $	Project Total $
Technology Assessment/Transfer & Outreach (cont'd)						
12381	Integra Environmental Consulting Inc.	Technical Assistance Related to Emission Inventories, Goods Movement and Off-Road Sources	04/06/12	04/30/18	110,000	110,000
12453	Tech Compass	Technical Assistance with Alternative Fuels, Fuel Cells, Emissions Analysis and Aftertreatment Technologies	06/21/12	05/30/18	75,000	75,000
14185	Three Squares Inc.	Conduct Education Outreach for the Basin DC Fast Charging Network Project	04/11/15	06/30/18	89,183	89,183
15380	ICF Resources LLC	Technical Assistance with Goods Movement, Alternative Fuels and Zero-Emission Transportation Technologies	12/12/14	12/11/18	30,000	30,000
15516	Cordoba Corporation	Technical Assistance with Construction of Zero Emissions Goods Movement Demonstration Project	03/27/15	03/31/18	74,500	74,500
17037	Clean Fuel Connection, Inc.	Technical Assistance with Alternative Fuels, Electric Vehicles, Charging and Fueling Infrastructure and Renewable Energy	11/18/16	11/17/18	100,000	100,000
17097	Gladstein, Neandross & Associates, LLC	Technical Assistance with Alternative Fuels and Fueling Infrastructure, Emissions Analysis and On-Road Sources	11/04/16	11/03/18	200,000	200,000
17282	Calstart	Cosponsor CALSTART's 25th Anniversary Symposium	03/22/17	01/31/18	15,000	150,000
17336	Three Squares Inc.	Conduct Education Outreach for the Basin DC Fast Charging Network Project	05/12/17	06/30/18	64,183	64,183
17358	AEE Solutions, LLC	Technical Assistance with Heavy-Duty Vehicle Emissions Testing, Analysis and Engine Development	06/09/17	09/08/19	100,000	100,000
18019	Ricardo Inc.	Technical Assistance with Heavy-duty Vehicle Emissions Testing, Analysis, and Engine Development and Applications	09/01/17	08/31/19	50,000	50,000
18120	Burke Rix Communications	Cosponsor the Southern California Energy Water & Green Living Summit 2018	12/06/17	02/28/18	5,000	150,000

Appendix C

Final Reports for 2017

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SCAQMD Contract #10482 **October 2017**

Install and Demonstrate a PEM Electrolyzer in Los Angeles, Providing Hydrogen Fueling for Vehicles and Utilizing the Technology in the Engineering Technology Curriculum at the University

Contractor
California State University Los Angeles

Cosponsors
The Ahmanson Foundation
Automobile Club of Southern California
California Air Resources Board (CARB)
California State University Los Angeles
U.S. Department of Energy (DOE)
Fran Morris-Rosman & Richard Rosman Trust
Kenneth Brasher ('62) Trust
MSRC/AB 2766 Discretionary Fund
South Coast Air Quality Management District

Project Officer
Larry Watkins/Joseph Impullitti

Background
The implementation of zero emission vehicles (ZEVs) is a key component in the effort to achieve air quality improvements in the South Coast Air Basin. Fuel cell electric vehicle (FCEV) technology is emerging at an accelerated pace and may play a crucial role in this effort. To accelerate this technology as a viable commercial alternative, the SCAQMD includes funding in its program allocations to support a network of hydrogen fueling stations throughout the Basin to support the operation and demonstration of FCEVs in the South Coast air basin. California State University Los Angeles (CSULA) submitted a proposal to SCAQMD and was awarded funding to construct and demonstrate a hydrogen research and fueling station with a polymer electrolyte membrane (PEM) electrolyzer. This project also complemented similar objectives and mandates of CARB and the DOE.

Project Objective
The project objective was to construct, install and operate a hydrogen research and fueling station including a PEM electrolyzer system in Los Angeles for the generation, compression, storage and dispensing of hydrogen on the CSULA campus. The station was intended to be a public access hydrogen station in support of FCEV technology as well as a research and educational tool as part of CSULA's engineering technology curriculum.

Technology Description
The station PEM electrolyzer produces hydrogen onsite from the splitting of water molecules. As powered by renewable energy electricity sources, this results in hydrogen production with a "zero carbon" fuel cycle. The station is capable of producing 60 kg per day and is matched with 60 kg of hydrogen storage capacity in ASME storage vessels. Hydrogen compression is accomplished via one PDC diaphragm type and two Hydropac high-pressure reciprocating type compressors, providing for both 350 bar and 700 bar fueling. The dispenser has two hoses, for respective 350 bar and 700 bar fueling events, and is capable of point-of-sale transactions utilizing major credit cards. Hydrogen is chilled to -20C, with typical refueling times of 6-8 minutes. Based upon typical refueling volumes, the station can fuel upwards of 20 vehicles per day.

Status
The CSULA fueling station encountered significant difficulties during construction. A lack of "buffer tanks" capacity, and a construction dispute over the same, stalled the project for over two years. Ultimately, the general construction

Figure 1: CSULA's H_2 Station interior (from left to right): high pressure compressors, H_2 chiller, 350 bar compressor, electrolyzer, 350 bar storage banks, visitor gallery

contractor could not finish the project, and CSULA took over construction and commissioning. After buffer tanks were installed, the station was for the first time capable of conducting fueling events on the 700 bar side without pressure pulsations. Another latent defect was discovered soon afterwards--incomplete NFPA leak detection in the dispenser programming. This was also a function of the previous lack of buffer tanks. However, permission to proceed with station operations was obtained from the State Fire Marshall, so long as protective measures in the form of attended fueling by trained personnel and manual leak monitoring were provided. With implementation of such an "attended fueling" protocol, improvement to station operations was able to proceed, pending the leak test programming upgrades. Quantum Technologies was tasked with leak test programming improvements.

The station successfully passed temporary certification to sell hydrogen by the kilogram from the California Division of Measurements Standards on October 23, 2014. Subsequently, the station made the first recorded sale of hydrogen by the kilogram on November 12, 2014, making the facility the first in the world to sell hydrogen fuel by the kilogram directly to retail customers. Furthermore, the station dispenser became the first in history to receive California commercial certification on January 8, 2014. Fueling contracts with several OEMs were also commemorated during these milestone events.

In its first few months, the station completed more than 250 vehicle fueling events. The station consistently makes 60 kgs of hydrogen available for fueling. Sufficient loading of the station is critical to maintain thermal balances and station reliability, and efforts continue to bolster utilization.

This contract closed in October 2017 following completion of data reporting and program management of the station for a three-year period. As of the closing of this contract, the station had limited access due to public accessibility issues.

Results

To date FCEVs from GM, Hyundai, Honda, Mercedes-Benz, Volkswagen and Audi have fueled at the station. The station is capable of producing 1800 kilograms of hydrogen per month, enough to fuel hundreds of vehicles producing only water vapor emissions. This is consistent with projected performance results.

Table 1: Three-year fueling throughput

Period	# of Fueling Events	kg sold
Nov 2014-Oct 2015	742	1,682
Nov 2015-Oct 2016	779	1,722
Nov 2016-Oct 2017	716	1,523
Total	**2,237**	**4,927**

Benefits

While no emission credits were associated with the construction of this station, hydrogen fuel displaces more traditional fossil fuels in mobile sources, thus reducing NO_x and achieving co-benefits for GHG emission reductions.

Project Costs

Projected costs for this project were $4,565,110. Final costs by cosponsor were as follows:

Cosponsors	Funding Amount
The Ahmanson Foundation	$200,000
Auto Club of Southern California	$50,000
CARB	$2,700,000
CSULA	$560,588
Fran Morris-Rosman & Richard Rosman Trust	$180
Kenneth Brasher (62') Trust	$10,000
MSRC/AB 2766 Disc. Fund	$250,000
SCAQMD	$250,000
DOE	$475,000
Total	**$4,495,768**

Commercialization and Applications

The station remains in operation despite public accessibility issues. However, CSULA and SCAQMD are evaluating solutions so the station can be utilized to its full capacity. Additionally, the hydrogen station was incorporated into CSULA's public outreach, research and education mission.

SCAQMD Contract #16039 **April 2017**

Demonstrate Prototype Hydrogen Sensor and Electronics Package

Contractor

Lawrence Livermore National Laboratory (LLNL)
Subcontractor: Los Alamos National Laboratory (LANL)

Cosponsors

U.S. Department of Energy (DOE)
South Coast Air Quality Management District

Project Officer

Lisa Mirisola

Background

Hydrogen safety sensors, both for filling stations and vehicle monitoring, are an integral part of the overall development of a hydrogen economy. Department of Energy (DOE) workshops, held to review hydrogen safety sensor requirements, identified performance targets for a variety of applications, with a focus on hydrogen refueling infrastructure and on-board fuel cell vehicles. These workshops highlight the dearth of commercially available hydrogen sensors capable of meeting sensitivity, durability, reliability and operational requirements at a cost which can accommodate wide-scale deployment.

Project Objective

The objective of this project was to co-fund demonstration of the LLNL/LANL hydrogen safety sensor at two hydrogen refueling stations - one in Burbank and one in Chino - and acquire performance data over a planned six-month demonstration period. Testing was conducted at the Burbank station operated by Hydrogen Frontier with positive results reported at the 2015 DOE Annual Merit Review. This project was also to continue monitoring at Burbank, including system upgrades for improved sensor communication and addition of a weather monitoring station.

Technology Description

The hydrogen safety sensor demonstrated employs electrochemical principles, relying on yttria-stabilized zirconium oxide—the same solid electrolyte upon which the broadly successful oxygen lambda sensor is based. Unlike lambda sensors, which operate at high temperatures where electrode reactions are dominated by thermodynamics, this hydrogen sensor operates at far lower temperatures where electrode kinetics (rates of oxidation and reduction of reactants) generate a non-equilibrium potential that dominates its response. The non-equilibrium electrochemical potential (also called a "mixed potential") develops due to differences in the redox kinetics of hydrogen at dissimilar electrode/electrolyte gas interfaces.

Figure 1: A close-up of a sensor element (left). Hydrogen sensor prototypes were installed at fueling station in Burbank (right) and Chino to assess their performance and long-term stability.

The demonstrated hydrogen safety sensor is unique, not only due to the mixed potential electrochemical phenomena, but because it uses a unique combination of electrode materials and a patented sensor design (U.S. Patent No. 7,264,700) that results in achieving stable and reproducible hydrogen response characteristics. The result is a new, highly sensitive electrochemical hydrogen safety sensor, designed with low cross-sensitivity and ultra-stable baseline, requiring minimal calibration and intrinsically resistant to false alarms.

Status

The demonstrations at Burbank and Chino hydrogen fueling stations were completed in April 2017 and were summarized in a final report due May 2017. Four progress reports are on file and the major tasks have been completed.

These tasks include:

1) selection of the Hyundai/Hydrogen Frontier fueling station in Chino, CA for the second demonstration site,
2) purchase and preparation of sensor elements, electronics and equipment necessary for field installation of two hydrogen sensor units and
3) sensor field trials unit/weather station installation and continuous monitoring for performance analysis.

Results

Field demonstrations clearly indicate that the sensors experience: minimal baseline drift, H_2 spikes in accordance with logged station release events, good sensitivity/ability to measure small, normal H_2 releases during routine station operation, no false positives during the entire field trials program, fast response time in the laboratory (<<1 s), which translates to the ability to clearly distinguish between filling events which occur within 10 minutes of each other, and low cross-sensitivity to water vapor and CO_2.

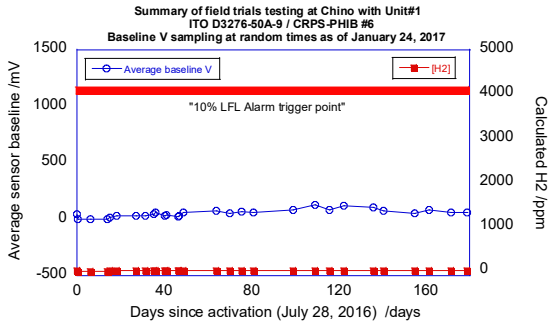

Figure 2: Sensor baseline voltage and corresponding H_2 measurement during prolonged exposure at the Chino fueling station over a 25-week period.

Benefits

This technology offers a solution for hydrogen emissions monitoring with minimal baseline drift, requiring infrequent calibrations/maintenance. The sensor responds rapidly to hydrogen releases with excellent sensitivity. Based on the performance recorded during this study, mixed potential sensors using an indium tin oxide electrode can meet U.S. DOE hydrogen safety sensor requirements.

Table 1: LANL/LLNL sensors meet U.S. DOE requirements

	EERE Table 3.7.2 [1]	LANL/LLNL sensor
Response time	< 1 s	<<1 s
Min detection limit	0.10%	10 ppm
Max detection limit	10%	5%
Accuracy	5% of full scale	<5% of full scale
Ambient temperature	-30 to 80 C	-30 to 125 C
Ambient humidity	10-98% RH	0-100% RH

[1] Buttner WJ, Post MB, Burgess R, Rivkin C (2011) International Journal of Hydrogen Energy 36(3):2462-2470

Project Costs

Project costs match projected spending. Of the SCAQMD funding allocated for this effort, $75,000 was applied to station selection, sensor installation, monitoring and analysis, and project management and reporting, $100,000 was used for sensor materials, deposition, construction, station selection, installation support and sensor monitoring/analysis. The total project costs were $350,000 with the U.S. DOE providing the remaining funding.

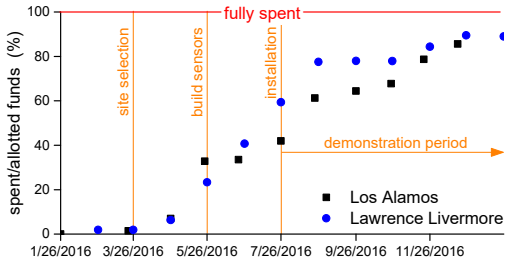

Figure 3: Expense over project duration, with milestone indicators.

Commercialization and Applications

This hydrogen safety sensor technology is an excellent candidate for commercial development to support hydrogen monitoring in fueling stations, hydrogen transportation vehicles, storage tanks and hydrogen fuel cell consumer vehicles. Efforts to optimize platform deposition and design for scale-up are underway. (If you wish to view the final report in its entirety, it has been assigned the release ID# LLNL-TR-725120.)

SCAQMD Contract #18118 **December 2017**

Participate in California Fuel Cell Partnership for CY 2017 and Provide Support for Regional Coordinator

Contractor
Frontier Energy

Cosponsors
7 Automakers
6 Public agencies
1 Technology provider
28 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. SCAQMD joined the CaFCP in April 2000, and the CaFCP currently includes 42 organizations interested in demonstrating fuel cell vehicle and fueling infrastructure technology.

Project Objectives
Goals for 2017:
- Decrease hydrogen station development time lines and costs
- Identify technology challenges and information gaps within the state's hydrogen station network
- Coordinate and collaborate on consensus approaches to achieving first 100 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.
- Facilitate implementation of two FCEB (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 demonstration effort. This final report covers the SCAQMD for 2017 membership. This contract was completed on schedule.

Figure 1: CaFCP organized tours of the El Dorado manufacturing plant in Riverside in August 2017 to look at fuel cell buses under assembly.

Technology Description
The CaFCP members together or individually are demonstrating fuel cell passenger cars and transit buses and associated fueling infrastructure in California. The passenger cars include Honda's Clarity, Hyundai's Tucson, and Toyota's Mirai. The fuel cell transit buses include 13 placed at AC Transit and five placed at Sunline Transit, one placed with Orange County Transportation Authority and one placed with UC Irvine Student Transportation.

Results
Specific accomplishments include:
- More than 3,000 consumers and fleets have purchased or leased passenger category FCEVs since they entered the commercial market in 2015;
- Transit agency members have 20 fuel cell electric buses currently in operation and more than 30 funded in 2016;
- There are 31 retail and four other non-retail hydrogen fueling stations in operation in California and 34 in development.

- CaFCP staff and members continue to conduct outreach and education in communities throughout California;
- CaFCP, the Governor's Office of Business and Economic Development and the California Energy Commission, continue advising and responding to city staff across the state of California to optimize station permitting.
- CaFCP created and maintains the Station Operational Status System (SOSS) that more than 30 hydrogen stations in the U.S. use to report status. This data, in turn, feeds real-time information (address, availability, etc.) to consumers through a CaFCP mobile-friendly website and several other apps and systems that support consumers.

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 $2 million, and includes facility 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. SCAQMD provides an additional $50,000 annually to support a Southern California Regional Coordinator and provides office space for additional staff in-kind at SCAQMD. SCAQMD's contribution for 2017 was $120,000.

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 effort. CaFCP members, individually or in groups, are focusing on the following important goals:

- 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 the public and community stakeholders on the role of FCEVs and hydrogen in the evolution to electric drive.

In 2018, the primary goals are the same as the 2017 goals listed above.

SCAQMD Contract #15626 **July 2017**

Develop, Integrate and Demonstrate Ultra-Low Emission Natural Gas Engines for On-Road Heavy-Duty Vehicles

Contractor

Cummins Westport, Inc.

Cosponsors

California Energy Commission (CEC)
Southern California Gas Company
South Coast Air Quality Management District

Project Officer

Richard Carlson/Joseph Lopat

Background

Heavy-duty on-road diesel vehicles are currently one of the largest sources of NO_x emissions in the South Coast Air Basin. This source category is still projected to be one of the largest contributors to NO_x emissions, even as the legacy fleet of older and higher-polluting vehicles are retired from operation and replaced by the cleanest available vehicles meeting the most stringent emission levels required by 2010 U.S. EPA emissions standards. The development of ultra-low emissions natural gas engines would significantly reduce emissions from this on-road heavy-duty source category and assist the region in meeting federal ambient air quality standards in the future.

Project Objective

Cummins Westport Inc.'s (CWI) objectives for this project were to develop and demonstrate an 8.9 liter natural gas engine suitable for on-road heavy-duty vehicle applications such as buses, refuse service, goods movement, and/or drayage trucks. The 'production-intent' engines and associated exhaust after-treatment technologies must be commercially viable and capable of:

- Achieving emissions targets of 0.02 g/bhp-hr NOx, 0.01 g/bhp-hr PM, 0.14 g/bhp-hr NMHC, and 15.5 g/bhp-hr CO,
- Keeping exhaust NH_3 emissions as low as achievable while targeting 10 ppm,
- Being thermally and fuel efficient, to achieve minimal fuel economy penalties relative to 2010 U.S. EPA and CARB certified diesel engines in similar duty cycle, and
- Being certified by the U.S. EPA and CARB.

Technology Description

An extensive process was undertaken to evaluate hardware and software changes on the engine and aftertreatment in order to achieve the project goals while being conscious about the impact on product costs and time for commercial development.

The selected technology architecture consisted of:

- Addition of a closed crankcase ventilation (CCV) system with pressure sensor,
- Addition of mid-catalyst temperature sensor,
- Aftertreatment size increase and improved composition of washcoat and precious metals, and
- Implementation of improved software with various emission optimizing control strategies.

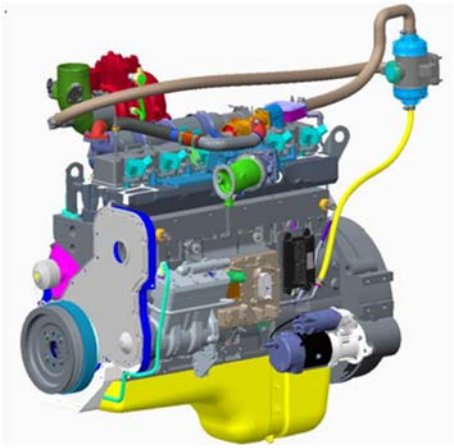

Figure 1: Cummins 8.9 liter ISL-G engine.

The CCV system consisted of a filter and hose assembly. The hoses route crankcase emissions to the filter where oil is separated and returned to the engine sump. The vapor is returned to the air intake where it mixes with intake air, fuel and EGR and enters the combustion chamber.

The additional CCV pressure sensor allows the control system to monitor pressure in the CCV system and alert the operator to issues as part of system diagnostics. The additional temperature sensor located mid-length on the catalyst allows the control

system to more quickly and accurately adjust fueling to minimize emissions. The combination of increased aftertreatment size and improved composition of washcoat and precious metals increases the overall conversion efficiency of the catalyst, thereby reducing emissions. The optimized control software targets high NO_x forming portions of the duty cycle and utilizes the above-mentioned hardware changes to reduce tailpipe emissions

Status

The project was successfully completed. While originally scheduled to be completed at the end of December 2016, the demonstration task was extended through to June 2017. The final report is on file with technical details of the project.

A variety of potential hardware and software changes were investigated early on in this project, resulting in the selection of engine and aftertreatment architecture. Prototype engines were built and tested in engine dynamometers and in engineering vehicles to further develop and validate the changes.

Full emissions certification testing was completed and submitted to CARB and U.S. EPA. In late 2015, CWI received emissions certification approvals from both CARB and U.S. EPA, meeting CARB's Optional Low NO_x 0.02g standard.

Thirteen pre-production engines were installed in seven refuse trucks and six transit buses and successfully operated in commercial service, accumulating over 560,000 miles and 61,000 hours of operation. Third-party chassis dynamometer testing of one of the demonstration refuse trucks was conducted by UC Riverside. The test showed the ISL G Near Zero "met and exceeded the target NO_x emissions of 0.02 g/bhp-hr and maintained those emissions during a full ration of duty cycles found in the South Coast Air Basin".

Results

The objectives of this project were achieved. Emissions certification was received from CARB and U.S. EPA to meet the CARB Optional Low NO_x 0.02g standard. While the stretch NH_3 target of 10 ppm was not achieved, ammonia emissions were reduced to less than 87 ppm measured in the cold hot emissions test cycle.

Thirteen demonstration vehicles successfully operated in commercial service accumulating 564,306 miles and 61,805 hours. Fuel efficiency was demonstrated on the transit demonstration vehicles at 3.39 to 3.83 mpdge (miles per diesel gallon equivalent), while UC Riverside estimated the fuel efficiency as 4.5 mpdge for the regional port cycle and

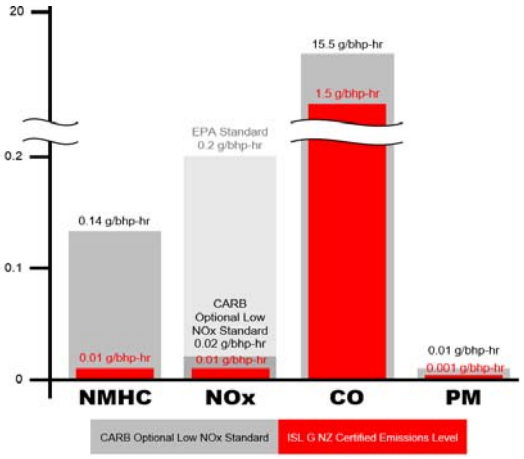

Figure 2: ISL-G emissions out-put

2.5 mpge for the CBD cycle. Notably, the technology development from this project initiated the commercial development of the ISL G NZ engine and aftertreatment.

Benefits

Parallel to this project, the ISL G NZ engine was commercialized and offered as a first-fit engine to vehicle OEMs covering refuse, transit and truck markets. The availability of an ultra-low emissions engine, specifically one that reduces NOx by over 90% from the current federal standard, enables air districts in North America to carry out their emissions reduction plans to meet ambient air quality goals, specifically reducing NOx emissions from heavy-duty on-road vehicles. To put the emissions reduction potential of vehicles powered by this ultra-low NOx engine into perspective, ten ISL G NZ powered buses produce the same NOx emissions as only one bus powered by a 2010 EPA-certified engine.

Project Costs

SCAQMD, CEC and SoCalGas contributed $3.5M. CWI's cost-share was approximately $3.7M, consistent with the expected project cost-share of $3,733,033. The total project cost was approximately $7.2M.

Commercialization and Applications

In parallel to this technology development and demonstration project, development of the ISL G NZ engine was successfully completed and the engine commercially launched in mid-2016. This engine is intended to be offered by the same wide range of vehicle OEMs and address the same applications as the current production ISL G engine. At project completion, the ISL G NZ powered vehicles were in commercial service in the transit and refuse service markets in California.

SCAQMD Contract #12028 **September 2017**

Demonstrate and Replace UPS Delivery Trucks with Zero Emission Medium-Duty Trucks

Contractor
Electric Vehicles International

Cosponsors
California Air Resources Board
United Parcel Service
South Coast Air Quality Management District

Project Officer
Joseph Impullitti

Background
Electric Vehicles International (EVI), United Parcel Service (UPS), SCAQMD and the California Air Resource Board (CARB) partnered together to create the Zero Emission Community-Level Goods Movement and Delivery Demonstration project in San Bernardino. This collaborative project provided funding for 40 zero emission vehicles at the San Bernardino UPS facility. As part of the project, the SCAQMD asked UPS to decommission one older diesel vehicle for every new zero emission vehicle.

Project Objective
EVI proposed to assemble and deliver 28 EVI walk-in medium- duty trucks to replace UPS diesel delivery trucks, which are located and operated in the City of San Bernardino. The replacement trucks will then be demonstrated in the UPS commercial fleet for a period of five years, during which UPS and EVI will collect data to evaluate performance, reliability, durability and emissions benefits of the EVI technology.

Shortly after the SCAQMD Board approved this project, CARB increased the incentive funding, which allowed an additional 12 vehicles to be delivered to San Bernardino for the same SCAQMD investment amount.

Technology Description
EVI, utilizing their signature all electric powertrain, worked with UPS to develop a zero emission, medium-duty and return-to-base delivery truck ideal for package delivery service providers. The new, class 6 vehicles use a Daimler Freightliner chassis with EVI's signature powertrain to create a zero emission, aerodynamic model of the walk-in vehicles that UPS drivers are accustomed to. The power system includes a 99 kWh lithium-iron magnesium-phosphate battery pack, which has a guaranteed battery life of 1,500 cycles, equivalent to five years of service in the UPS fleet.

Figure 1: Class 6 medium-duty return-to-base delivery vehicle

Status
As of May 2012, EVI delivered all vehicles to UPS in San Bernardino. Shortly after, a few of the initial vehicles returned to EVI for upgrades to increase durability. In early 2014, UPS placed all 40 electric vehicles into service at their San Bernardino facility.

As an integral part of this project, EVI and UPS continued to collect telematics from each vehicle for the five-year demonstration period. At the conclusion of this contract, EVI was required to submit a final report and two-page project synopsis including data on the five-year demonstration period.

Results
UPS placed the majority of the vehicles into service in mid-to-late 2013. EVI has calculated the

environmental benefits for calendar year 2013, with anticipated reductions in fuel usage and commensurate benefits for calendar years 2014-2017.

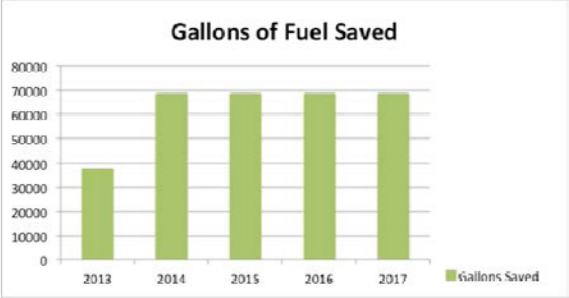

Figure 2: Fuel savings over reporting period

In 2013, over 300,000 zero emission miles were driven in San Bernardino. In 2013, UPS saved over 34,000 gallons of diesel fuel for a total dollar savings of roughly $145,000, which is estimated to be doubled over the remaining four years of the project.

Benefits

Estimates show this demonstration project will provide an annual reduction of 8.39 short tons of NO_x and .30 short tons of $PM_{2.5}$ per year.

Additionally, in terms of co-benefits for criteria pollutant reductions, it is anticipated that almost three million zero emission miles will be driven, resulting in a total CO_2 reduction of roughly seven million pounds through the term of this project, as summarized below.

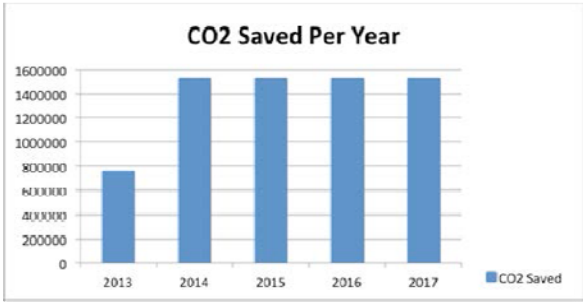

Figure 3: CO_2 savings over reporting period

Project Costs

The initial project cost for the 28-vehicle deployment was just over $4.8 million. The final project cost for the 40-vehicle demonstration deployment including the infrastructure funding for UPS San Bernardino facility was $7.4 million.

EVI's initial vehicle cost was just over $168,000 per truck. With the durability upgrades, the current vehicle price was approximately $186,000.

SCAQMD's initial investment of $1.4 million remained unchanged. The cost of the additional 12 vehicles added to the demonstration was provide by CARB.

Commercialization and Applications

Zero emission electric vehicles are on the brink of transforming the return-to-base delivery vehicle market, providing significant emission reductions.

One of the biggest obstacles to fleet commercialization is the higher vehicle incremental cost. With the right amount of incentive funding, however, it is anticipated that delivery fleets would be willing to transition away from diesel vehicles.

Additional large vehicle orders will also help manufactures lower vehicle costs, ultimately providing a more competitive vehicle cost compared to their gas or diesel counterparts.

SCAQMD Contract #13396 **September 2017**

Develop and Demonstrate Seven Class 8 Zero Emission Electric Trucks

Contractor

Transportation Power, Inc. (TransPower)

Cosponsors

California Energy Commission (CEC)
U.S. Department of Energy (DOE)
Port of Long Beach
Port of Los Angeles
South Coast Air Quality Management District

Project Officer

Brian Choe

Background

On-road heavy-duty diesel trucks are a significant source of diesel particulate matter and NO_x emissions with serious health effects. The impact on public health is more pronounced in the surrounding communities along the goods movement corridors near the Ports of Los Angeles and Long Beach, and next to major freeways in Southern California. Recognizing the significant impact diesel trucks have on air quality and public health, the SCAQMD has been working with other regional stakeholders, including the Ports of Los Angeles and Long Beach, to promote and support the development and deployment of advanced zero emission cargo transport technologies in the South Coast Air Basin. Deployment of zero emission trucks in this region may also be a future requirement for conforming to rules, regulations, and mandates of SCAQMD, CARB, EPA, and DOE, while also helping to foster economic development in the region.

Project Objective

The initial objective of this project was to develop, build, and demonstrate four zero emission Class 8 battery electric drayage trucks in real world drayage service operations to accelerate the introduction and penetration of electric transportation technologies into the cargo transport sector. This project was one of four zero emission drayage truck technologies funded by a grant from the Department of Energy under the Zero Emission Cargo Transport (ZECT) Demonstration program. The vehicles were intended to be demonstrated in real world drayage service for two years in partnership with Transportation Services, Inc. or other SCAQMD approved fleets in the Basin. This objective did not evolve significantly during the contracting procedure, but the technologies enabling this demonstration did evolve substantially, as discussed in the next section. In addition, the total size of the TransPower demonstration fleet was increased from four to seven trucks.

Figure 1: A demonstration vehicle equipped with Inverter-Charger Unit

Technology Description

The TransPower ElecTruck™ drive system uses a unique combination of two 150 kW permanent magnet motors that were originally developed for the Fisker Karma hybrid passenger car. The demonstration vehicles were equipped with Inverter-Charger Units (ICUs) that combine the functions of the vehicle inverter and battery charger. This innovation minimizes external charging infrastructure and charges each truck in less than 4 hours, providing operational flexibility and reducing capital costs. An Automated Manual Transmission uses proprietary software to control a transmission shift mechanism, enabling operation in multiple gears to maximize vehicle efficiency. High-energy battery modules using lithium iron phosphate cells were installed on all trucks, providing 70-100 miles of range under

normal operating conditions. A proprietary vehicle control system optimizes vehicle efficiency, maximizes battery life, and protects key components such as batteries and power electronics from excessive temperatures, voltage spikes, or current surges.

The ElecTruck™ principle of operation differed from other equipment available at the start of the ZECT project, but by the end of the project multiple competitors were offering electric drive options employing onboard chargers and AMT technology, which were demonstrated in Class 8 trucks for the first time on this project.

Status

The ZECT project was completed in September 2017. Testing of one of the ZECT trucks on a chassis dynamometer at the University of California, Riverside (UCR) in 2014 showed the ElecTruck™ technology to be nearly twice as efficient as competing electric drive technologies. The major unanticipated problem encountered during the project was the reluctance of fleet operators to use drayage trucks with the 70-100 mile range limitation. Despite this challenge, the seven trucks accumulated 43,000 miles of use during the project, far surpassing the number of miles accumulated on any other fleet of electric Class 8 trucks to date. On-going advances in battery technology are expected to address the range limitation issue, making electric trucks of this type attractive to an expanding array of users over the next several years.

Results

The UCR final report documenting the results of its dynamometer tests concluded that "The TransPower electric HDV [heavy-duty vehicle] was almost two times more energy efficient than an all-electric HDVs tested at UCR in 2011 over the same cycles. This suggests the current all-electric HDV is a significant improvement in the state of the art HDVs." This testing, along with in-service demonstrations, showed the practicality of zero-emission operation of Class 8 trucks. The UCR report also concluded "the all-electric HDV performed well on all the cycles and showed a very reliable operation from full to 20% SOC load," while concluding that the energy cost of operating the TransPower electric truck compared favorably with the costs of operating diesel trucks or competing electric trucks.

In this case, there were few performance tradeoffs. Achievement of emissions reductions, improved efficiency, and lower operating cost all worked hand in hand.

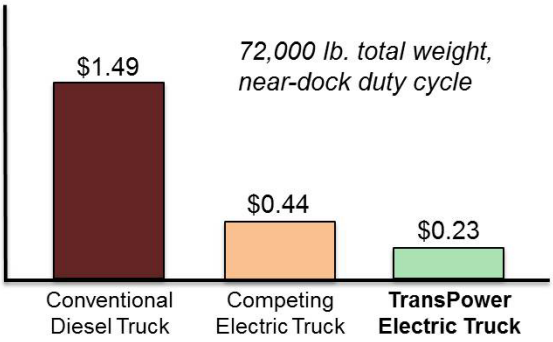

Figure 2: Energy Cost per mile - Class 8 On-Road truck

Benefits

The actual benefits of the ZECT project compare favorably with the benefits anticipated at the project's start. The technology can clearly reduce air pollutants while helping to address global warming because it offers a zero-emission solution for goods movement, one of the leading sources of criteria pollutants and carbon emissions.

Project Costs

The total cost of the ZECT project was approximately $5.1 million, of which the SCAQMD's funding contribution was just over $1.5 million, including $375,000 from the Clean Fuels Fund. These costs exceeded initial estimates due to expansion of the fleet from four to seven trucks and more intensive technology development.

Commercialization and Applications

Evidence is mounting that electrification of Class 8 trucks has great commercial potential, driven by reductions in battery costs and the market entry of major players such as Tesla and Cummins. Two months after the conclusion of the ZECT project, major OEM supplier Meritor made a significant investment in TransPower. The potential size of the U.S. electric Class 8 truck market is in the tens of thousands of trucks per year, and if long-haul trucks can eventually be addressed, as some believe, hundreds of thousands of trucks per year.

SCAQMD Contract #14224 **February 2017**

Develop and Demonstrate Long Range All-Electric Transit Bus

Contractor
Complete Coach Works (CCW)

Cosponsors
EV Grid
Denso
South Coast Air Quality Management District

Project Officer
Brian Choe

Background
Electrification of the current US transit is seen as a method of reducing one of the large contributors of greenhouse gas emissions in urban areas. Through the efforts in this project to further the technology in targeted areas, Complete Coach Works (CCW) hopes to expand the overall effectiveness of its all-electric transit busses.

By increasing the energy efficiency and improving the overall range of the bus, CCW gets closer to developing a product that can rival existing internal combustion engine vehicles.

Project Objective
Electric buses are transforming the transit industry. This project developed and deployed a third generation all-electric transit bus, increasing the range on a single charge, reducing the vehicle curb weight, and improving the vehicle efficiency. The bus will deploy an advanced high energy density battery to reduce the battery pack weight and improve the vehicle range from 120 to 150 miles.

Technology Description
In order to improve the overall efficiency of the existing all-electric transit bus, CCW targeted six specific areas; the propulsion, HVAC, auxiliary and lighting systems as well as focusing on weight reduction and low rolling resistance tires.

Propulsion System: Installing a 130 kW high efficiency, high power, liquid cooled drive system which improved the acceleration and speed performance of the electric bus. The new drive system also significantly improved the regenerative braking performance allowing longer range on a single charge.

HVAC System: Using direct DC 300V system instead of 240V AC system eliminated the DC to AC conversion requirement which in turn eliminated energy losses associated with this conversion.

Auxiliary Systems: Using 220V DC auxiliary systems such as power steering pump and air compressor improved the efficiency and performance of these systems.

Weight Reduction: Using higher energy density batteries and using light weight battery packaging is the key for achieving the balance between the range and the vehicle weight. After careful analysis and engineering design, CCW selected lithium ion NMC batteries. The new design batteries have almost twice the energy density of lithium iron phosphate batteries currently used.

Lighting System: Using advanced low power LED systems for interior and exterior lighting improved the rider experience and conserved energy.

Low Rolling Resistance Tires: Tire rolling resistance is a major aspect of the vehicle range. As the transit bus operates in the stop-and-go driving pattern, the average speed is less than 15 MPH. At these speed levels, road drag is higher than aerodynamic drag. CCW addressed this issue by using low rolling resistance tires, enhancing the range on a single charge and improving the energy efficiency of the vehicle.

Status
Complete Coach Works has completed the SCAQMD sponsored demonstration project for an all-electric repower package exclusively designed

for the transportation industry in February 2017. CCW has successfully operated from coast to coast with the transit bus, promoting CCW's electric bus conversion technology to various transit agencies, including Orange County Transportation Authority in Southern California.

Results

Through this project, CCW has been able to demonstrate an operating range of more than 150 miles on a single charge on this unit. Depending on the driver and environmental conditions, the goal of between 120-150 miles on a single charge is achievable.

Table 1: Comparison of Gen 2 and Gen 3 Buses

Description	*Gen 2 Bus*	*As Built Gen 3 Bus*
Launch Date	May 2013	Aug 2015
Bus Chassis	Low Floor 40 Foot	Gillig Low Floor 40 Foot
Battery Pack Size	242 KWh	311 KWh
Battery Chemistry	Lithium Iron Phosphate	Lithium ion NMC
BMS System	Voltage and temp monitoring	Voltage and temp monitoring with optical communication
Battery System Weight	5,900 lbs	3,800 lbs
Motor peak kW rating	150 kW	150 kW
Maximum Motor torque	2000 NM	2500 NM
On Board Charger	40 kW	50 kW
Charging input	480V	480V /208V

Benefits

Through significant weight reductions and efficiency gains wherever possible, CCW was able to increase the operating range for the Gen 3 Bus in an effort to reach comparable ranges with a conventional engine bus. It still needs further improvement, but CCW has shown that as the technology evolves, it is getting closer to provide sufficient ranges with these electric buses in commercial applications.

There are more than 4,000 transit buses operating in Southern California. If most of these units can be replaced with all-electric zero emission buses, a significant reduction in air pollution as well as greenhouse gases as co-benefit can be achieved for the region.

Project Costs

Total project cost was $1,039,649 and SCAQMD funded $395,000 with CCW cost sharing the remaining $644,649.

Commercialization and Applications

Demonstration projects help identify improvements in efficiencies around the climate in which the buses operate. For instance, a bus that operates perfectly in Palm Springs, California in the winter and summer time may not represent the same performance that will be expected in Central Washington. As CCW learns and identifies the expectations of agencies across the country, CCW can continue to fine tune its system. It will also continue to improve the vehicle efficiency by applying lessons learned from the past and on-going demonstrations.

As can be expected, cost essentially revolves around volume. Typically, the greater the volume, the more that the cost can be driven down. Cost effectiveness however comes with experience. CCW has had a steady stream of orders and continues to identify areas of improvement, while maintaining a cost parameter which is still about 40% less than what an agency can buy a new zero emission bus.

The North American Bus Market is roughly 6,500 buses sold per year, and Complete Coach Works' Zero Emission Propulsion System (ZEPS) is now commercially available. With that said, remanufactured vehicles do not fit every agencies business model or replacement cycle. As budget concerns loom with the new administration, agencies everywhere are looking for a more cost effective way to operate its fleets, and this is where CCW can fill a niche. The numbers are hard to predict, but CCW is in full force making transit authorities across the country aware of the electric repower option. On average a CCW ZEPS bus is on par with the cost of a new diesel product, so CCW is confident that agencies that would want to adopt electric buses will be able to do so.

SCAQMD Contract #07246 **June 2017**

Purchase and Install New LNG Storage Tank at Long Beach LNG Refueling Station

Contractor

USA Waste of California Inc., a subsidiary of Waste Management

Cosponsors

Waste Management
South Coast Air Quality Management District

Project Officer

Larry Watkins/Phil Barroca

Background

Waste Management (WM) owns and maintains a facility for waste hauling trucks located at 1970 E. 213th Street in Long Beach, CA 90810. WM is dedicated to doing business in sustainable ways possible, as well as offering its customers more ways to live green via the air quality benefits of natural gas heavy duty vehicles. Consequently, of the nearly 1,000 vehicles operating in WM's Los Angeles metropolitan territory, almost half are natural gas vehicles. In fact, WM has one of the largest fleets of heavy-duty natural gas trucks in North America. To fuel this natural gas fleet and to provide limited access to other public and private fleets, WM planned for the installation of an additional above-ground LNG 16,000 gallon storage tank at its Long Beach facility. WM applied for and received $200,000 co-funding from the SCAQMD as cost-share for the installation of the storage tank as well as related work for site improvements.

Project Objective

WM's objective was to add approximately 16,000 gallons of additional LNG storage capacity to an existing 16,000 gallons for a total capacity of approximately 32,000 gallons at its existing limited-access LNG fueling station in Long Beach. Proposed related work would include site improvements and process piping and controls related to the added storage capacity. Installation also would include services to survey, cut, saw and remove asphalt, change grade and install a new concrete pad in the fueling area.

The purpose of the project was to reduce emissions from heavy-duty refuse collection vehicles by expanding existing infrastructure to fuel extremely low-emission natural gas vehicles, as well as to provide the infrastructure needed in order to make alternative fuels like natural gas a commercially viable and preferable fueling option. WM would operate the expanded LNG station at its Long Beach facility.

Figure 1: LNG Tank Installation

Technology Description

Equipment to be installed includes one additional above-ground storage tank with a capacity of approximately 16,000 gallons, an offload pump/transfer pump and all associated civil work, and a 50 SCFM vapor compressor with associated hardware. All equipment meets AGA, ANSI, API, ASME, ASTM, NEC, NFPA, OSHA and SAE requirements.

Status

WM chose Northstar LNG as its contractor to procure and install the equipment including the additional LNG tank. The new station became operational in June 2012. No significant problems were encountered during the construction of the project. Waste Management will operate the expanded station for a minimum of five years and continue reporting to the SCAQMD during that period, as required under this contract.

Results

Now that the additional LNG storage installation and related work is complete, the station can adequately fuel its natural gas fleet plus offer limited access to other public and private fleets. The availability of natural gas fueling at the expanded station will result in cost savings due to the lower cost of natural gas as a fuel coupled with the air quality benefits achieved by displacing diesel fuel.

WM exceeded SCAQMD's required throughput of 1,000,000 DGE by the end of the third full year of operation. By the end of the full five years of reporting, cumulative DGE was 1,450,655 annually.

Table 1: Five-Year Fuel Throughput Snapshot

Period	WM LNG Usage	Third-Party LNG Usage
July 2012-June 2013	1,032,187	222,610
July 2013-June 2014	1,031,451	190,068
July 2014-June 2015	1,143,306	177,696
July 2015-June 2016	1,184,761	276,158
July 2017-June 2017	1,191,766	258,889
Total	**5,583,471**	**1,125,421**

Benefits

Natural gas (NG) is a clean, safe and abundant fuel that is domestically produced, with 99 percent of NG used in the U.S. coming from North America. The successful installation of this additional storage tank will provide increased fueling capacity to fuel natural gas vehicles operated by WM and other public and private fleets. Additionally, WM will continue to expand its natural gas fleet in Southern California in order to replace diesel fuel use in its operations.

In addition to cost savings realized with lower costs of natural gas (costing less per energy unit than diesel), natural gas contains less carbon than other fossil fuel and thus produces lower CO_2 and GHG emissions annually. In fact, natural gas vehicles produce 20-30 percent less GHG emissions than comparable diesel vehicles.

Project Costs

The anticipated cost of the tank installation and related site improvements was $440,000. Final project costs, however, were $822,604. While the $440,000 budget covered the cost of equipment, the additional costs over that amount included further site improvements that were necessary in order for WM to install the additional equipment. Specifically, the bulk of the additional costs were the result of installing the offload pump and all associated civil improvements.

Commercialization and Applications

This project will provide the additional infrastructure needed in order to make alternative fuels like natural gas a commercially available and preferable fueling option. Commercial fleet drivers and owners of LNG-equipped vehicles can now fuel at WM's newly upgraded Long Beach station.

Figure 2: Rear View of Tank Installation and New Equipment and Components

Additionally, public and private fleets may consider switching to natural gas as additional infrastructure is available, due to both the environmental and cost-savings benefits. This project is also beneficial to those vehicles subject to Rule 1193, which requires public and private solid waste collection fleets having exclusive contracts with public entities and greater than 15 trucks to purchase or replace existing vehicles with alternative fuel vehicles.

SCAQMD Contract #08098 **April 2017**

Purchase and Install New CNG Fueling Station

Contractor
Redlands Unified School District (RUSD)

Cosponsor
South Coast Air Quality Management District

Project Officer
Larry Watkins/Phil Barroca

Background
In 2003, the Redlands Unified School District (RUSD) initiated participation in the SCAQMD's Lower-Emission School Bus Replacement Program, desiring to replace its fleet of older diesel-powered school buses with alternative fueled vehicles. The first CNG-powered school buses acquired by the RUSD were fueled at the City of Redlands transportation yard. As additional CNG-powered school buses were acquired, the RUSD realized its fiduciary responsibility required installation of a permanent on-site time-fill CNG fueling facility. The RUSD applied for and received funding from the SCAQMD under its Clean Fuels Program to construct a CNG fueling station. At that time the RUSD had 11 CNG school buses in its fleet, with plans to add at least one additional CNG bus to its fleet every year.

Project Objective
The objective of this project was to construct a combination slow-fill and buffered fast-fill natural gas vehicle refueling facility for the RUSD to refuel its natural gas school buses on-site, both to meet present and projected future needs. The station would be located at 955 E. Citrus Ave. in Redlands, CA 92374. This objective was to be accomplished in two phases. The first phase, funded primarily by the SCAQMD through its Lower-Emission School Bus Replacement Program using AB 923 funds, was to install fueling posts and a temporary slow-fill fueling station. The second phase, primarily funded under this contract award, consisted of three parts:

1) electrical upgrades of the transportation facility;
2) installation of a permanent combination slow-fill and buffered fast-fill natural gas station; and
3) additional infrastructure improvements required by the City of Redlands.

Technology Description
The new station would be comprised of a compressor pad to mount equipment (east side of existing garage), two 100 SCFM Greenfield skid-mounted compressors, gas conditioning equipment, controls and all ancillary equipment, two 33.5 cubic feet CNG storage spheres, 9 new and 13 upgraded time-fill fueling posts, one buffered fast-fill dispenser, and installation of safety features including emergency shutdown devices. Subsequently, RUSD determined electrical upgrades would be required to meet electrical needs of the new station.

Figure 1: Skid-Mounted Compressors and CNG Storage Spheres

Status
The RUSD hired a consultant to develop station bid specifications. The job was publicly bid, with Allsup Corp. eventually awarded the contract in March 2010 to build the facility and FBA Engineering to design electrical upgrades for installation by Beaumont Electric. During preliminary construction, the City of Redlands moved to impose a Conditional Use Permit (CUP) process on the job, requiring the RUSD to submit construction documents for review.

While the RUSD was initially reluctant to accept the CUP because it would delay the work and increase costs, after considerable discussion, the RUSD agreed and contracted with Epic Engineering to assist. Construction plans as well as civil drawings were submitted for review. It took one year from the time the City of Redlands requested the RUSD submit a CUP application to the City issuing the CUP.

The City of Redlands, as a condition of approval, required the school district to construct curbing and sidewalks along Citrus Ave. and new drive approaches (ADA-compliant), as well as planting fast-growing vines along the exterior fence. Finally, the school district was required to grant the City unrestricted access to a storm drain which traverses the property. Phase II including the permanent combination station was completed in mid-February with RUSD Board of Education project approval on April 24, 2012. Within one year of the new station going online, the RUSD had added five new CNG school buses to its fleet, displacing five diesel school buses.

Figure 2: Bus Fueling with Slow-Fill Nozzle

This contract ended in April 2017, after RUSD provided five years of annual reporting on throughput and station status.

Table 1: Throughput for Five-Year Snapshot

Period	Throughput (Therms)
Mar 2012-Feb 2013	58,593
Mar 2013-Feb 2014	52,960
Mar 2014-Feb 2015	99,079
Mar 2015-Feb 2016	107,210
Feb 2016-Mar 2017	107,210

Results

For the first 11 months of operation, from February to December 2012, a total of 48,829 CCFs (hundred cubic feet) were consumed. Using a conversion formula of 1.2119205298 CCFs per gallon (U.S.) of gasoline, the CNG station saved 42,290 gallons of diesel fuel. In terms of NO_x and PM emissions, 5.1278 tons of NO_x were taken out of the air and PM has been reduced as well. These reductions will increase as RUSD replaces more of its diesel and gasoline school buses with CNG-fueled school buses.

Indeed, at the conclusion of this contract, the RUSD's fleet of 74 buses now comprises: Propane-6; CNG-33; Gasoline-12; and Diesel-23. And in 2017, RUSD added three dual-nozzle timefill posts to enable fueling of six more buses.

Benefits

In addition to the air quality benefits achieved (e.g., reduced NO_x and PM emissions) by switching from diesel to natural gas, construction of the fueling facility has allowed the RUSD's Transportation Services to significantly cut operational costs. In addition to a surcharge added to the fuel cost by the City of Redlands shortly after construction, the department was scheduling approximately 1,400 additional hours annually to fuel at the City's transportation yard. Within one year of station construction, fuel and labor cost savings to the school district equaled $35,000 annually.

Project Costs

Projected bid costs were anticipated at $657,918, including $26,103 for electrical work. Actual project costs were as follows:

Table 2: Actual Project Costs

Task	Cost
Development of bid specifications	$12,665
Electrical upgrades to the Transportation Facility	$37,755
Installation of slow-fill and buffered fast-fill NGV refueling station	$673,297
Facility upgrades imposed by the City of Redlands Conditional Use Permit	$98,186
TOTAL STATION COST	**$821,903**

Of this $821,903, the SCAQMD funded Phase II under this contract award in the amount of $525,000, with an additional $14,000 through the Lower-Emission School Bus Program. The RUSD contributed $282,903.

Commercialization and Applications

Of the 23 diesel-powered school buses still remaining in RUSD's fleet, 11 were manufactured prior to 1994. RUSD, however, recently applied for funding through SCAQMD's Lower-Emission School Bus Replacement Program to replace all 11 with new CNG-fueled school buses. Construction of the permanent on-site station allowed for the conversion of RUSD's fleet to alternative fuel and continues to reap benefits to the school district.

SCAQMD Contract #12135 **November 2017**

Upgrade CNG Fueling Station

Contractor

Placentia-Yorba Linda Unified School District (PYLUSD)

Cosponsors

Southern California Gas Company (SoCalGas)
South Coast Air Quality Management District

Project Officer

Larry Watkins/Phil Barroca

Background

Following the enactment in 2001 of SCAQMD's Rule 1195 – Clean On-Road School Busses, which requires school districts with 15 or more buses in their fleet to purchase alternative-fueled buses when adding or replacing buses in their fleet, Placentia-Yorba Linda Unified School District (PYLUSD) has been committed to achieving the environmental benefits available by transitioning to alternative-fueled school buses. However, at that time, of the 82 buses in the District's fleet, only six were eligible for replacement under the SCAQMD's Lower-Emission School Bus Replacement Program. Prior to the purchase of these six CNG buses, PYLUSD's fleet was fueled exclusively by diesel and unleaded gasoline.

In addition to assisting PYLUSD with the purchase of the six CNG-fueled school buses, the SCAQMD provided funding for a slow-fill fueling system which was installed at the district bus yard. Unfortunately, the fueling system, manufactured by Fuelmaker which later went bankrupt, barely met district needs and irreparably broke down in January 2010. This required PYLUSD to travel up to 40 miles per day to off-site fueling facilities. Furthermore, the capacity of the existing CNG compressor had limited the school district to the six existing CNG buses.

Project Objective

The primary objective of this project was to replace the existing natural gas compressor with a larger capacity compressor, enabling reliable on-site refueling as well as the capacity to enlarge PYLUSD's natural gas fleet. The project would also increase electrical supply and gas flow and add two more slow-fill posts to the existing four slow-fill posts. PYLUSD also wanted to ensure that parts would be available for future repairs from a variety of sources.

Technology Description

By upgrading compressor capacity from 8 SCFM to 25 SCFM, additional CNG-fueled vehicles could be added to the PYLUSD's fleet, displacing even more diesel-fueled vehicles from operation. The compressor installed was a reconditioned Bauer/P500 air-cooled high pressure unit at 3600 psi. New electrical equipment included a dedicated circuit (480 volt/3 phase/40 amp) coming from the main transformer.

Figure 1: PYLUSD Bauer/P500 Compressor

Status

PYLUSD initially hired Environmental Vehicle Services to determine the design output required to reliably fuel its existing six CNG buses yet have the capacity for growth in its natural gas fleet. The school district then solicited bids and awarded a contract to S-W Compressors to complete the project, which is now 100% completed. The electrical supply to the compressor pad was upgraded to 480v3 as of December 2011. The compressor unit was delivered in January 2012, with final start-up and testing in August 2012. SoCalGas also upgraded the gas meter to handle the additional throughput. Commissioning of the equipment occurred on September 4, 2012. There were no unanticipated problems during this project. Under the SCAQMD contract, the upgraded station must operate for a minimum of five years during

which annual reporting will be provided to the SCAQMD.

During the first seven months of operation, a total of 14,138 therms of natural gas were used to fuel the school district's fleet, averaging about 2,020 therms per month.

The following table shows throughput for the first five years of station operation as required under this contract:

Table 1: Throughput for Five-Year Period

Period	Therms
Sept 2012 - Aug 2013	18,505
Sept 2013 – Aug 2014	29,839
Sept 2014 – Aug 2015	35,662
Sept 2015 – Aug 2016	33,178
Sept 2016 – Aug 2017	18,531

Results

All objectives of this project were accomplished without any major problems from design phase to start-up. Additionally, the project was accomplished under budget. The overall project has successfully enabled PYLUSD to fuel its existing natural gas fleet on-site. In fact, another four CNG school buses were ordered soon after completion of the upgrade and it is anticipated that the upgraded station will be capable of fueling the new buses as well. As of the conclusion of this contract term, PYLUSD has 11 natural gas vehicles in its fleet.

Benefits

By re-establishing on-site fueling for the school district's CNG-fueled school buses, the benefits are substantial. It has allowed the PYLUSD to eliminate 8,000 miles of travel annually to and from off-site fueling facilities and reduced fueling costs because off-site NG stations were not passing on the 50 cent per gallon federal tax rebate plus adding a price markup as well. Combined, it is estimated this will result in a cost savings of $40,000 annually to PYLUSD.

The air quality benefits are also substantial. One study concluded CNG-fueled trucks produce 75% less CO, 49% less NO_x and 95% less PM than comparable diesel trucks. In such a heavily trafficked community, continuing this level of pollution was not a viable option for the school district. The cleaner NG school buses also provide a co-benefit in GHG emission reductions.

Project Costs

PLYUSD anticipated up to $60,000 in expenses for the replacement of its CNG compressor and related work. However, final costs came in under budget as follows:

Table 2: Actual Project Costs

Equipment	Cost
Electrical Upgrades	$4,305
Reconditioned Compressor (including labor)	$50,000
Total Project Costs	**$54,305**

The SCAQMD paid 100% of the project costs with PYLUSD simply providing in-kind costs to administer the project. As noted, however, SoCalGas provided in-kind services by upgrading the gas meter to handle higher output.

Commercialization and Applications

PYLUSD is located in the north east corridor of Orange County where there is significant traffic around the intersections of the 91, 55 and 57 freeways. The school district's school bus fleet is located at 1301 E. Orangethorpe Avenue, Placentia, CA 92870. PYLUSD owns the fueling station and will be responsible for its maintenance and operation. Maintenance and support have been contracted out and the new system has exceeded the school district's performance expectations. The upgraded on-site fueling station is benefitting the school district, its students and the surrounding community.

SCAQMD Contract #14311 **December 2017**

Construct CNG Fueling Station in Murrieta

Contractor

Southern California Gas Company (SoCalGas)

Cosponsors

California Energy Commission (CEC)
Mobile Source Air Pollution Reduction Review Committee (MSRC)
South Coast Air Quality Management District

Project Officer

Phil Barroca

Background

The widespread use of alternative fuel powered vehicles in the South Coast air basin play an important role in helping this region meet national ambient air quality standards for fine particulates and ozone. To support the local deployment and expansion of alternative fuel vehicles, the SCAQMD has leveraged its funds with other funding sources and fleet operators to increase the network of both public and private alternative fueling stations within the South Coast air basin. Under this project, the SCAQMD was awarded a grant from the CEC under AB 118 Program PON-11-602 to install a new public/private CNG station with the Southern California Gas Company (SoCalGas) located at their facility in Murrieta, CA.

Project Objective

This project with SoCalGas cost-shares the purchase of equipment for the installation and upgrade of a CNG fueling station located at their facility at 41376 Guava St. Murrieta, CA 92562. This station is positioned near the junction of the I-15 and I-215 freeways and is projected to provide greater accessibility to CNG fuel, which in turn will help foster greater deployment and expansion of CNG vehicles in this region. The station will serve the needs of SoCalGas's growing natural gas-powered vehicle fleet as well as the public and surrounding fleets. The station design is intended to easily accommodate large trucks and buses. The publicly accessible dispensers will be open 24 hours/day, seven days/week. The station hosts two dual-hose fast-fill dispensers and significant on-site storage will provide the 24/7 public access side of this facility with improved filling speed and increased reliability. The facility will also include 10 time-fill posts that can fill 36 vehicles concurrently.

Figure 1: Public Access Fast-Fill

Technology Description

This station includes a 125 horsepower, 500 standard cubic feet (scf) per minute compressor, two fast-fill dispensers and ten time-fill posts. Eight of the time-fill posts are equipped with four hoses and the other two posts have two hoses for a total of 36 hoses to provide simultaneous overnight fueling. The station includes a 34,000 scf compressed gas storage system. The public access portion of the station is located outside the SCG facility gate and consists of a new fueling island with two fast-fill dispensers each with two nozzles, rated at a minimum of five gasoline gallon equivalents (GGEs) per minute, a universal card reader and the capacity to add a second compressor in the future.

Status

The SoCalGas Murrieta CNG station was successfully commissioned and opened for business in September 2015. Throughput during Calendar Year 2016 was 53,767 GGE. Throughput for Calendar Year 2017 increased to 176,000 GGE, with public fueling accounting for 90% of total annual throughput. Assuming a 50:50 gasoline-diesel displacement and 176,000

GGE per year of CNG, the estimated GHG reductions are 400 metric tons/yr.[1]

Results

The primary goal of this project was to increase availability of CNG infrastructure, to enhance California's energy independence by reducing petroleum-based transportation fuel consumption, and to reduce criteria and toxic air pollutants and greenhouse gas emissions. The annual throughput projected in the proposal for this project was 210,000 GGE per year at full utilization (after three years). Original annual throughput projections were estimated based on the following key assumptions: the Riverside Transit Agency (RTA) indicated their intention to fuel ten transit buses at this station and SoCalGas had vehicle procurement plans to place 40 NGVs at the Murrieta base by 2015. From the time the original proposal was prepared and submitted (early 2012) to the time the station was deemed operational in late 2015, RTA built its own station in Hemet. Located 23 miles East Northeast of the Murrieta station. Furthermore, the growth of the SoCalGas fleet was curtailed because of the delays in station commissioning and a shift in corporate plans. With full commissioning, SoCalGas domiciles 16 NGVs and reported 176,000 GGE throughput in 2017. However, two local school districts use this facility as a back-up to their own fueling stations: Temecula Valley USD has a slow-fill, and Murrieta Valley USD has both slow and fast-fill operations. Murrieta Valley and SoCalGas have a Mutual Aid agreement for emergency fueling.

Figure 2: Time-fill Posts

Figure 3: Public Signage

Benefits

This CNG station project was commissioned in September 2015 and has been operating successfully and continuously for more than two years. The original projections placed throughput at 210,000 GGE/year. The annual throughput for 2017 totaled 176,000 GGE which equates to approximately 400 metric tons of CO_2e of GHG reduction. Although the station is not achieving the projected throughput yet, there is significant public usage. Most importantly, this publically accessible CNG station helps fill a critical gap in CNG fueling infrastructure as it is now the southern-most public access CNG fuel station in Riverside County since the Downs Energy-Temecula LCNG station closed business in 2017. Indeed, it is the only publicly accessible station along 60 miles of the I-15 corridor between Corona and San Marcos, CA.

Project Costs

Original project estimates were $878,200; final project costs, $1.6 million. The higher costs were due in part to the prolonged timeframe between project start and finish as well as the decision to add a second dispenser, additional infrastructure required by the City of Murrieta, and upgrading the facility to accommodate an additional compressor in the future. The SCAQMD administered the project, providing $217,000 in CEC pass-through funds, and cost-share of $150,000 was also provided by the MSRC.

Commercialization and Applications

The design and convenience of the new Murrieta station is expected to appeal to consumers based on location along an important transportation route in Riverside County, and its ability to handle large trucks and buses with ease. The facility is expected to provide heavy-duty vehicle operators with a great experience at the pump where they can fill very quickly, using a large enough compressor and making sure the station has enough space so that the large vehicles can easily maneuver. Other features that help provide an improved experience for customers include ergonomic fuel dispensing nozzles that swivel easily to attach to the vehicle, drought-tolerant landscaping and a well-lit canopy that covers the fueling dispensers day or night, rain or shine. Additionally, the station's monument sign clearly shows the price so people can see from the road how relatively inexpensive the fuel is relative to gasoline or diesel.

[1] ***Appendix D. Quantification Methodology for Determining Emission Reductions and Cost Effectiveness****, Low Carbon Transportation and Fuels Investments and the Air Quality Improvement Program, CARB May, 19 2017.*

SCAQMD Contract #10722 **September 2017**

Re-Establish Testing Facility and Quantify PM Emission Reductions from Charbroiling Operations

Contractor

University of California, Riverside, Center for Environmental Research and Technology (CE-CERT)

Cosponsors

U.S. Environmental Protection Agency
South Coast Air Quality Management District

Project Officer

Michael Laybourn

Background

The South Coast Air Quality Management District (SCAQMD) is classified as "serious" non-attainment area for $PM_{2.5}$. Studies have shown that PM emissions from the under-fired charbroiler process are primarily in the submicron range (greater than 85% by mass <1.0µm).

Recent Air Quality Management Plans (AQMPs) have included control measures intended to reduce $PM_{2.5}$ emissions from under-fired charbroilers at commercial restaurants. CE-CERT previously developed a testing protocol for chain-driven charbroilers and was selected to conduct a preliminary screening analysis to determine the effectiveness of several under-fired charbroiler control devices in reducing PM emissions.

Project Objective

The main project objective was to re-establish the testing facility at CE-CERT and provide additional funds to help defray testing costs for control device manufacturers. After completing the necessary test kitchen upgrades, CE-CERT evaluated promising commercial or near-commercial control technologies using established procedures. It should be noted that this effort represented initial screening tests of the control devices and more detailed "protocol" testing would be necessary to further document control device effectiveness in reducing PM emissions. The re-established test kitchen has also been used for subsequent CE-CERT testing with additional funds provided by SCAQMD, Bay Area AQMD and U.S. EPA.

Figure 1: CE-CERT Test Kitchen Facility

Technology Description

A total of three emissions control technologies were selected for initial testing. The first technology, InnovaTech, was an aerosol grease removal prototype that is based on a patented technology for particle (solid or liquid) separation from an incoming flow stream via Boundary Layer Momentum Transfer (BLMT) theory.

Figure 2: InnovaTech NovaMist™ Unit

The second technology, OdorStop™2000C developed by Green Kitchen Designs, featured three stages of progressively more efficient

filtration with additional screening tests conducted on modified systems.

The third technology was an electrostatic precipitator (ESP) developed by Airquest International, Inc. The technology removes particles, which range in size from 0.01 micron to 10 microns, with high efficiency.

Status

This program has been completed. The test kitchen was re-established and screening tests on three control technologies was performed according to the contract requirements. Final reports have been received. No anticipated problems were encountered during the screening tests, however, the contract was extended until June 2017 to conduct additional testing using supplemental funds provided by U.S. EPA and SCAQMD.

Results

Table 1 shows results from the screening tests performed on the following control technologies; InnovaTech, Green Kitchen, and Airquest. The screening tests showed that all three technologies resulted in large $PM_{2.5}$ reductions compared to baseline testing (i.e., without control technology). These reductions ranged from 59.6% to 93%.

Project results can be used in support of future efforts to reduce PM emissions from under-fired charbroilers. As noted, these results are from screening tests which are based on real-time air monitoring equipment. Protocol evaluations based on U.S. EPA method 5.1 and SCAQMD testing procedures are necessary to further evaluate control device effectiveness.

Table 1: Screening test results for PM emissions

	PM (mg/m3)	% PM Reduced
InnovaTech Screening Tests		
Baseline	250.5	
InnovaTech	101.2	59.60%
Green Kitchen Concepts Screening Tests		
Baseline 1	218.9	
HEPA Filter	18.6	91.5%
99% Filter	15.8	92.8%
95% Filter	26.3	88.0%
Baseline 2	581.5	
99% Filter	157.3	>72.9%
95% Filter w/fog	67.7	>88.3%
99% Filter w/PCO double pass	100.1	>82.8%
Airquest Screening Tests		
Baseline	161.9	
Airquest Single Pass	17.1	89.40%

Benefits

This program has helped to identify promising control technologies to reduce $PM_{2.5}$ emissions from under-fired charbroilers. This study will also support the efforts of other $PM_{2.5}$ non-attainment areas, such as the San Joaquin Valley, in efforts to identify cost-effective control technologies for this source category.

Project Costs

The total cost of this project was $321,700 with $60,000 funded by Clean Fuels. Approximately half of SCAQMD Clean Fuels project costs were allocated to test kitchen re-establishment and the other half to fund control device testing. Total project funding is summarized in the table below:

Table 2: Actual Project Costs

Cosponsor	Amount
U.S. EPA	$45,700
SCAQMD	
Fund 31-Clean Fuels	$60,000
Rule 1309.1 Priority Reserve Fund	$216,000
Total	**$321,700**

Commercialization and Applications

Testing conducted by CE-CERT and demonstration projects conducted in the San Joaquin Valley show control technology for under-fired charbroilers has continued to develop over the past few years. However, identification of affordable, commercially-available $PM_{2.5}$ control technologies, especially for retrofit projects at existing restaurants, remains elusive. The 2016 AQMP adopted by the SCAQMD Governing Board includes a contingency control measure to develop a regulation intended to reduce $PM_{2.5}$ emissions from under-fired charbroilers which could be implemented if necessary to meet Clean Air Act requirements, provided appropriate control devices can be identified. Results from this and other studies could be used in support of any potential rule development effort.

SCAQMD Contract #14162 **June 2017**

Utilize Fleet DNA Approach and Capabilities to Provide Vehicle Vocational Analysis within SCAQMD

Contractor
National Renewable Energy Laboratory (NREL)

Cosponsors
U. S. Department of Energy
South Coast Air Quality Management District

Project Officer
David Coel/Phil Barroca

Background
With highway transportation responsible for over half of the oil demand in the U.S., medium- and heavy-duty vehicles (MDVs and HDVs) consume a significant portion of on-road fuels annually and consequently contribute significantly to regional air pollution, particularly in the high vehicle populated and goods movement area of Southern California's South Coast basin. OEMs, commercial fleets and research organizations have identified a lack of usage data for MDVs and HDVs as a barrier to intelligent vehicle design and deployment. Compiling and analyzing in-use vehicle data helps identify average and extreme use patterns for various types of vehicle vocations as well as identifying similar use patterns across dissimilar vocations, potentially leading to more optimized and efficient designs that are appropriate for multiple uses.

The National Renewable Energy Laboratory (NREL) and U.S. Department of Energy (DOE) have been conducting research, development and demonstration projects to facilitate the deployment of advanced vehicle technology and alternative fuels into the marketplace in order to reduce petroleum use and enhance the reduction of mobile source emissions in California and the U.S. In a joint collaboration, NREL and the SCAQMD agreed to conduct a project to collect and analyze data on MDVs and HDVs in the South Coast air basin to analyze usage characteristics and develop an approach which could enable the SCAQMD to better understand vocational differences and associated vehicle performance.

Project Objective
The project objective was to acquire and analyze field data from MDVs and HDVs operating in the SCAQMD. NREL was to identify and work with local and regional commercial fleet operators and collect in-use data using NREL supplied hardware and personnel. The data collected is to be processed through NREL's Drive-Cycle Rapid Investigation, Visualization, and Evaluation (DRIVE) analysis software tool to add to the FleetDNA database that houses performance characteristics of multiple sets of vehicles operating throughout the country. SCAQMD data will be analyzed, compared, and reported back to the SCAQMD. Additional analysis will utilize NREL's Future Automotive Systems Technology Simulator (FASTSim) to explore and identify powertrain options and technologies that match the observed drive/duty cycles.

Figure 1: DRIVE™ Analysis Tool

Figure 2: FASTSim

Technology Description
NREL performed an assessment to categorize the medium- and heavy-duty (Class 3–8) on-road commercial vehicle vocations predominant in the SCAQMD. The size and age of the vehicle population was ascertained by acquiring and mining data from the R.L. POLK MDV and HDV registration database. Estimated annual vehicle miles travelled and estimated fuel usage were ascertained by leveraging the U.S. DOT's Vehicle In-Use Survey (VIUS) database, the Oak Ridge National Laboratory's Transportation Energy Data Book and CARB's EMFAC model. NO_x emissions from the various vehicle types, weight classes and model years were calculated by an NREL developed method that relates NO_x emissions from different engine emission certification levels to fuel economy. Data collected and developed were

inputted into NREL's Scenario Evaluation, Regionalization & Analysis (SERA) model to estimate the contribution of each vocational category to the total emissions inventory in the SCAQMD.

Status

Using fleets recommended by SCAQMD, from May to August 2015, NREL deployed data loggers to collect data from 60 Class 8 drayage and transfer vehicles within the SCAQMD. NREL also leveraged recent data logging activities within these vocations that took place within SCAQMD boundaries including data collected by NREL under the California Hybrid Truck and Bus Voucher Incentive Project (HVIP) and phase 1 of the DOE-funded Zero Emission Cargo Transport (ZECT 1) Project. In the HVIP, NREL collected 1 hertz (defined as one cycle per second) vehicle data between October 2012 and September 2013 from 62 delivery vehicles for 2 to 3 weeks, each including model year 2007-2013 vehicles from UPS, Aramark and FedEx. Data from the ZECT 1 project included data logging of drayage service from the TTSI fleet, including 149 days of conventional baseline vehicle operation on 2 trucks and 26 days of operation of the TransPower electrified drayage trucks.

Results

NREL modeled the effects of rolling resistance, aerodynamic drag, vehicle mass reduction, CNG engines and vehicle electrification. Over 2,100 real-world delivery truck (Class 3-7) trips were recorded. The results show that the stop-and-go nature of delivery trucks will benefit more from mass reduction than from rolling resistance reduction or aerodynamic improvements, saving fuel from reduced mass on every acceleration. Conversely, they do not typically drive enough miles for rolling resistance improvements to have the same impact and they do not drive enough at high speeds for aerodynamic improvements to save substantial amounts of energy. When routes are within the range of EV powertrains, large savings can be realized but payback due to the cost of batteries and electric rate structure must be considered on an individual site basis. Simulations of delivery truck routes showed EVs using significantly less energy than their diesel counterparts (approx. 1.3 kWh/mile EV vs. 4.4 kWh/mile diesel) The duty cycle data showed that approximately 80% of daily driving was less than 70 miles per day, which could be accomplished with a 100 kWh battery pack. CNG, while somewhat less efficient on an energy basis, may offer fuel cost savings when natural gas prices remain below diesel without negative emissions contribution. Refueling infrastructure costs and on-board storage limitations must also be considered when considering CNG vehicles.

Over 800 real-world transfer truck (Class 8) trips were also recorded. EVs were not considered because of the long daily driving distances–90% of the daily driving was over 100 miles. Transfer trucks will benefit more from mass reduction and rolling resistance reduction than from aero-dynamic improvements. While current EV technology cannot provide the range needed, CNG engines can provide the range needed and offer possible fuel cost savings when natural gas prices remain below diesel.

Over 1,800 real-world drayage truck (Class 8) trips were recorded. Drayage trucks will benefit more from mass reduction than from rolling resistance reduction or aerodynamic improvements and mass reduction on the tractor is the aspect most under the control of the fleet operator. CNG and EV powertrains offer advantages that are completely separate from the chassis and container designs. EV powertrains are a good fit for drayage vehicles if the daily driving distance is within the range of a specific vehicle design and battery usage can be maximized. CNG vehicles also work well and can provide the range needed for the full spectrum of drayage operations and offer possible fuel cost savings for the full spectrum of routes.

Benefits

An analysis and assessment of the drive and duty cycles of various commercial vehicles can provide insights into improving vehicle energy efficiencies that in turn translate into lower emissions or less energy needs. The study also provided analyses on the alternative fuel technologies available for these vehicle vocations that could further reduce emissions from the transportation sector.

Project Costs

Project costs totaled $199,985, with SCAQMD providing $174,985 and DOE in-kind of $25,000.

Commercialization and Applications

Vehicle use data can help with intelligent vehicle design and deployment and identify average and extreme use patterns for various types of vehicle vocations or similar use patterns across dissimilar vocations which could lead to more optimized and efficient designs that are appropriate to multiple uses.

SCAQMD Contract #15623 **March 2017**

Evaluate Ozone and SOA Formation from Gasoline and Diesel Components

Contractor

University of California, Riverside, College of Engineering Center for Environmental Research and Technology (CE-CERT)

Cosponsors

South Coast Air Quality Management District

Project Officer

Naveen Berry

Background

Direct evaporation from unburned gasoline and diesel fuels is an established source of ozone and secondary organic aerosol (SOA) forming precursors. As new vehicle control technologies continue to decrease primary organic aerosol and gas-phase emissions, whole fuel evaporation becomes a more significant potential source of ambient organic aerosol. Therefore, determining the SOA forming potential of whole gasoline and diesel vapor is of significant interest. While SOA formation from some gasoline components such as aromatics have been individually studied under controlled conditions, there are only a few studies on how these complex mixtures behave in the atmosphere.

Given changes in fuel formulations over time, it is important to revisit whole gasoline as an important SOA precursor, especially in light of increased knowledge on the impact of reactivity on aerosol formation and improved atmospheric chambers and instrumentation.

Project Objective

Objective 1: Evaporative Loss Study

a. Collect gasoline and diesel fuels from local fueling stations. (Ten samples each)
b. Evaluate the evaporative emissions for select diesel fuels using a modified version of CE-CERT evaporative chamber system.
c. Measure the vapor pressure of gasoline and diesel.

Objective 2 – Ozone and SOA Study – Gasoline and Diesel

a. Perform a series of environmental chamber experiments to evaluate the ozone and SOA formation from whole gasoline and diesel in the presence of a surrogate mixture. Follow standard environmental chamber operating procedures to measure and characterize particle formation and ozone generation.
b. Conduct detailed hydrocarbon analysis for gasoline sample.
c. Modify injection method for injection of whole diesel fuel using systems developed for (low vapor pressure-volatile organic compounds) LVP-VOC injection.

Technology Description

The UCR U.S. EPA chamber consists of two ~90,000-liter Teflon® reactors located inside a 16,000 cubic foot temperature-controlled "clean room" that is continuously flushed with purified air. The clean room design is employed in order to minimize background contaminants into the reactor due to permeation or leaks. The primary light source used in this study consists of 272 115W Sylvania 350BL blacklights. The interior of the enclosure is covered with reflective aluminum panels in order to maximize the available light intensity and to attain sufficient light uniformity, which is estimated to be ±10% or better in the portion of the enclosure where the reactors are located. The reactors are attached to a semi-flexible moveable framework that allows the reactors to be emptied between experiments and reduces the volume under positive pressure control to prevent dilution due to sampling or leaks during experiments. A high-volume mixing system with Teflon® pipes and Teflon®-coated flanges is used to mix the reactors and to exchange reactants between the reactors to achieve equal concentrations when desired.

An AADCO air purification system that provides dry purified air at flow rates up to 1500 liters min-1 is used to supply the air to flush the enclosure and to flush and fill the reactors between experiments. The air is further purified by passing it through cartridges filled with Purafil® and heated Carulite 300® which is a Hopcalite®-type catalyst and also through a filter to remove particulate matter. The measured NO_x, CO, and non-methane organic concentrations in the purified air were found to be less than the detection limits of the instrumentation employed.

The chamber enclosure is located on the second floor of a two-floor laboratory building that was designed and constructed specifically to house this facility. Analytical instrumentation (except for the PM instrumentation) is located on the ground floor beneath the chamber or on the second floor immediately adjacent to the chamber enclosure. The particle sizing instrumentation is located within the enclosure to ensure sizing is conducted at the same temperature as the experiment to prevent evaporation and/or condensation during analysis.

Status

The project was completed in December 2016. The final report is on file with complete technical details of the project.

Results

The SOA formation observed from the diesel fuel was 15 times higher than that of the gasoline samples. Trends of SOA formation with aromatic content are not observed, possibly because the surrogate mixture used is normalizing the reactivity of the system whereas in the previous work the aromatics were serving as both SOA precursors and as a source of increased system reactivity. Aromatic content of the diesel fuel cannot nearly explain the SOA formation observed for diesel and therefore other precursors (e.g., intermediate VOCs or LVP-VOCs) are much more significant contributors to SOA formation than previously observed.

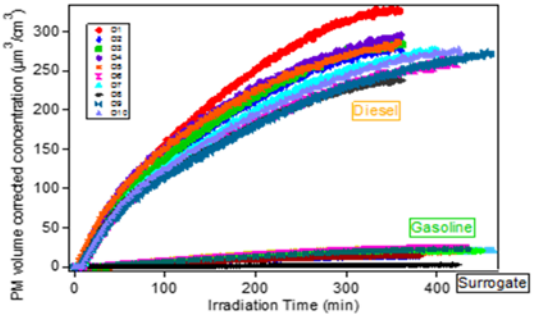

Figure 1: SOA formation from gasoline and diesel with surrogate and H_2O_2

Compared with ozone formation from the surrogate and H_2O_2 only run, the ozone formation from winter blend gasoline reduced the O_3 formed from the surrogate mixture. Similar trends were observed for diesel experiments; ozone formation from all the diesel samples was reduced with surrogate and H_2O_2. This may be attributed to larger changes in radical concentrations, NO_x loadings, etc. occurring within the environmental chamber than are expected to occur within the more complex ambient atmosphere with its more significant reservoir.

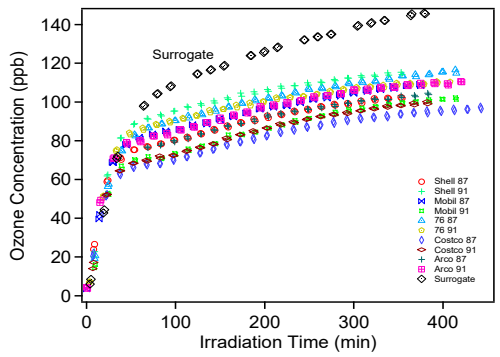

Figure 2: Ozone formation from individual winter blend gasoline with surrogate H_2O_2

The higher the NO_x concentration, the higher the ozone and SOA formed for both gasoline and diesel. This indicates that the fuels are likely acting within the environmental chamber system as a NO_x sink reducing the total reactivity of the system. Therefore, addition of greater quantities of NO_x are leading to greater consumption of SOA precursors than in systems with lower NO_x concentrations. However, in the atmosphere there are continued sources of NO_x, which allows the reactivity to be maintained. The trends here demonstrate the importance of NO_x but do not actually imply that lower NO_x levels in the atmosphere will actually lead to lower SOA formation.

The volatility for gasoline and diesel SOA decreased during the period of the experiments. Gasoline SOA was more volatile than diesel SOA. Both gasoline and diesel SOA are very hydrophobic. Compared with gasoline SOA, diesel SOA was not oxidized that much.

Benefits

The current work provides estimates of the relative SOA and ozone formation from whole evaporated gasoline and diesel fuels under reactive conditions similar to South Coast air basin needed to more accurately evaluate evaporated fuel impacts on SOA within the South Coast air basin. The work clearly demonstrates a far more significant role of non-aromatic IVOC precursors in SOA formation and provides preliminary analysis of the impacts of SOA formation from the whole fuel as NO_x loadings are reduced in the South Coast air basin.

Project Costs

The actual total project cost was $75,000.

Commercialization and Applications

The research conducted in this work provides fundamental ozone and SOA formation data from a variety of in-use diesel and gasoline fuels within the South Coast air basin. More accurate representation of the SOA formation of the whole evaporated fuel was determined by utilizing a surrogate atmospheric mixture designed for the South Coast air basin. VOC precursors beyond that of the simple monocyclic aromatics were identified as important SOA precursors suggesting the need for further evaluation of the impact of these VOCs from fuels and other sources on fine particulate pollution within the South Coast air basin. Preliminary results further suggests SOA formation dependence on atmospheric NO_x loadings that requires additional future research to best project changes in SOA formation as the South Coast air basin NO_x loadings are reduced. No new physical technology was developed for commercialization.

SCAQMD Contract #16198 **January 2017**

Study Opportunities and Benefits of Deploying Next Generation Heavy-Duty Natural Gas Vehicles Operating on Renewable Natural Gas

Contractor

Gladstein, Neandross & Associates (GNA)

Cosponsors

California Natural Gas Vehicle Partnership (CVGNP)
Pacific Gas & Electric (PG&E)
American Gas Association (AGA)
Clean Energy Fuels, Inc.
Southern California Gas Company (SoCalGas)
Agility Fuels Corporation
South Coast Air Quality Management Dstrict

Project Officer

Phil Barroca

Background

The SCAQMD, Southern California Gas Company (SoCalGas), Pacific Gas & Electric (PG&E), the American Gas Association (AGA), the California Natural Gas Vehicle Partnership (CNGVP), and Agility Fuels Corporation joined to cosponsor a white paper exploring the Opportunities and Benefits of Deploying Next Generation Heavy-Duty Natural Gas Vehicles Operating on Renewable Natural Gas (RNG). Next generation refers to the latest near-zero-emission (NZE) technology for heavy-duty vehicles (HDVs) recently certified by Cummins Westport, Inc. (CWI) to CARB's optional ultra-low NO_x standard of 0.02g/bhp-hr. The wide-scale use of NZE HDVs in the South Coast air basin would have significant air quality benefits relative to HDVs certified to the current NO_x standard (0.2g/bhp-hr). The emission benefits of NZE technology is complemented further by the use of RNG which has carbon intensity values far below conventional fuels and fossil-based natural gas resulting in significantly lower greenhouse gas (GHG) emissions.

Project Objective

The objective of this project was to prepare a major government-industry funded white paper that describes the opportunities, environmental benefits, challenges and costs associated with deploying NZE NO_x heavy-duty natural gas engines using increasing volumes of RNG. A specific objective of this study was to demonstrate how NZE engines in HDVs can help the South Coast air basin cost effectively attain federal ozone standards by key deadlines, while helping California meet aggressive State goals to reduce GHGs through the increased use of RNG to displace fossil-based conventional and natural gas fuels.

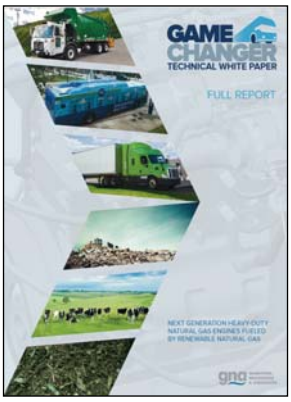

Figure 1: White paper completed in April 2016

Technology Description

In 2015, CWI introduced the world's first CARB-certified NZE heavy‑duty engine, the L9N. The L9N is an 8.9L spark-ignited natural gas-powered engine that employs a closed crankcase and larger three-way catalyst (TWC) system lowering tailpipe NO_x by more than 90% relative to the federal NO_x standard and tailpipe methane emissions by 70 percent to reduce this engine system's fuel-cycle GHG emissions and short-lived climate pollutants (SLCP). Complementing this system's lower GHG emission is the use of RNG as the engine fuel. RNG is produced from organic products such as disposed of green and food wastes that are collected in municipal refuse. These organic materials that would normally decompose and produce GHGs in a landfill are contained, converted, cleaned and compressed into CNG for use as a transportation fuel or for introduction to the natural gas pipeline system. CARB's Low Carbon Fuel Standard program (LCFS) and EPA's Renewable Fuel Standard program are designed to quantify and reduce the carbon intensity (CI) or GHGs of transportation fuels as well as the nation's dependency on petroleum-based fuels. These programs incentivize the production and use of renewable fuels through the issuance and tracking of LCFS and Renewable Identification Number (RIN) credits that can be traded in their respective markets. RNG has been identified as having some of the lowest CI values which result in higher credit value.

Status

The "Game Changer" white paper was completed in April 2016 and released at the ACT Expo 2016 conference in Long Beach. The paper has been widely cited by regulators like SCAQMD, clean transportation advocates, the heavy-duty NGV industry, providers of renewable fuels, and municipalities seeking to address environmental justice issues.

Results

With help from SCAQMD and the other project cosponsors, GNA was highly successful in widely disseminating the technical white paper. It has helped pave the way in California (and nationwide) for government clean-vehicle grant funding programs to identify new, larger streams of funding to deploy near-zero-emission heavy-duty NGVs, especially when using RNG. In sum, the paper is being used in the South Coast air basin and across the U.S. as an important tool to expand commercialization and deployment of HDVs powered by NZE natural gas engines and bring greater awareness of RNG.

Benefits

Near-zero-emission natural gas engines provide a commercially proven, broad−based and affordable strategy to immediately achieve major reductions in emissions of criteria pollutants, toxic air contaminants and GHGs from America's on-road HHDT sector. As documented in the report, the key to achieve National Ambient Air Quality Standards (NAAQS) for ozone and $PM_{2.5}$ in the South Coast air basin, and other air basins is to aggressively control NO_x from HHDTs. Analysis indicates that attaining the ozone NAAQS in the South Coast air basin will require rapid, very large NO_x reductions from HHDTs over the next five to 10 years. The report describes how heavy-duty NZE natural gas engines provide a major tool to achieve such large NO_x reductions, as rapidly and cost-effectively as possible.

Wide-scale use of RNG can provide major GHG reduction benefits. Moreover, the act of producing RNG can offer an array of localized environmental and economic benefits, including job creation, improved air quality, and a number of environmental waste stream management improvements. RNG production is a highly sustainable process via multiple pathways; various types of waste streams (that are otherwise environmental hazards requiring costly treatment or processing) are converted to energy-rich, locally-produced renewable energy sources that ultimately displace higher-pollution non-renewable fuels. This simultaneously generates significant economic value and multiple other benefits, as documented in the report.

Used together to replace conventional diesel HDVs, this fuel/engine technology can immediately and uniquely begin delivering 90 percent (or greater) reductions in NO_x emissions for the large U.S. fleet of on-road HDVs, while simultaneously proving GHG reductions of 80 percent or greater.

Project Costs

Total project costs are broken down by organization as follows:

Organization	Amount
American Gas Association	$50,000
CNGVP	$50,000
Clean Energy	$50,000
SoCal Gas	$50,000
Pacific Gas & Electric	$50,000
Agility Fuels Corporation	$10,000
SCAQMD	$50,000
Total	**$310,000**

Commercialization and Applications

Heavy-duty NGVs with NZE engines are already helping to transform America's diesel-dominated freight movement system. CWI's L9N engine is now commercially available in a broad range of HDV sectors that power freight movement and public transportation systems (transit buses, refuse haulers, and short-haul delivery trucks).

In 2018, CWI will certify and commercialize a NZE 11.9 liter natural gas powered engine, the ISX12N. This engine will expand on-road applications of NZE HDVs into HHDTs used in high-fuel-use goods movement applications, including for-hire long-haul trucking. CWI has also certified its 6.7-liter B6.7N engine to CARB's 50 percent optional low-NO_x standard (0.1 g/bhp-hr), and it is now commercially available for certain applications. Spurred on by CWI's achievement, other heavy-duty engine manufacturers are now working to certify and commercialize other near-zero-emission heavy-duty gaseous fuel engines.

Finally, production and use of RNG continues to grow in California, and across the U.S. Today, approximately 60% of the natural gas consumed in California transportation applications is RNG.

SCAQMD Contract #16254 **December 2017**

Evaluate Ozone and Secondary Aerosol Formation from Diesel Fuels

Contractor

University of California, Berkeley

Cosponsors

Gulf of Mexico Research Initiative
South Coast Air Quality Management District

Project Officer

Naveen Berry/Diana Thai

Background

Diesel vehicle exhaust and unburned diesel fuel are major sources of intermediate volatile organic compounds (IVOCs) and may contribute to the formation of urban ozone and secondary organic aerosol (SOA), which is an important component of fine particulate matter ($PM_{2.5}$). The characterization of IVOC emissions is critical in assessing ozone and SOA production rates in urban locations, such as the South Coast air basin.

Project Objective

Traditionally, laboratory measurements of IVOCs have been prohibitively difficult. For this project, novel experiments, measurements, and emissions modeling of several diesel blends under varying temperatures and wind speeds were used to determine potential ozone and SOA formation related to evaporative emissions, particularly in urban areas.

Technology Description

This project combines wind tunnel experiments with state of the art gas chromatography with mass spectrometry (GC-MS) quantification methods. These experiments and measurements verify and allow the application of a thermodynamic model of diesel evaporation that combines current knowledge of ozone and SOA formation to estimate pollutant production under varying conditions. The combination of cutting edge measurements and modeling with reliable wind tunnel experiments is a major advancement in prediction of pollutant formation from evaporation of complex mixtures containing IVOC, which include low-vapor pressure VOC.

Status

The project was completed in December 2017. Major project milestones were enhancing an existing wind tunnel apparatus to allow temperature control of the evaporating liquid. The next milestone was verifying agreement between our thermodynamic model and measurements for all 100+ species that showed significant evaporation under our experimental conditions. Finally, our model showed the importance of IVOC emissions from complex mixtures such as diesel to the formation of both ozone and SOA on timescales relevant to ambient air quality standards (8 hrs, 24 hrs). In addition to the initial goals, emissions and pollutant formation were modeled for 1 month time periods to show longer term effects.

An unanticipated problem was unreliable analysis of many diesel samples using our novel GC-MS methods. Our soft ionization source, which allows unprecedented detail in composition, did not initially provide results that were comparable from day to day. We worked extensively with the manufacturer to resolve this issue for our samples. After ensuring a sound data set for this work, several more days of intensive work revealed that we could modify the ionization voltage in the mass spectrometer to give not only reliable results but also the potential for enhanced composition information in future analyses.

Results

Key results from this work include:

1) Detailed composition of several diesel blends during evaporation experiments
2) Modeled ozone formation from evaporative emissions
3) Modeled SOA formation from evaporative emissions.

The compositions of several diesel blends were analyzed utilizing a new technique, gas chromatography with soft-electron-impact-ionization time-of-flight mass spectrometry (GC-SEI-MS), which gave unprecedented composition.

Commercially available blends had similar compositions, with about 25% aromatic content and aliphatic content that was dominated by branched, cyclic compounds. Two synthetic blends covered lower (15%) and higher (45%) aromatic content. Our model of evaporation accurately modeled the composition of all these blends during evaporation over 24 hours for all evaporation conditions spanning 1-3 m/s wind speed and 20-40˚C.

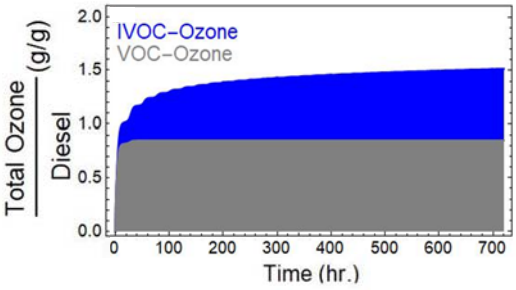

Figure 1: Ozone formation during1 month of diesel evaporation.

As illustrated in Figure 1, it is clear that IVOC are consistently an important part of ozone formation, culminating in 45% of ozone formation after 1 month of evaporation. The rest of the ozone formation is due to VOC emissions. Yields for the mixture presented here (Mobile) are also significant, ranging from 1 to 1.5 g-ozone/g-Diesel released.

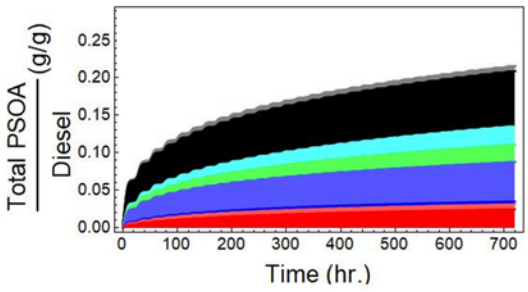

Figure 2: Potential SOA (PSOA) formation during 1 month of diesel evaporation. Aromatics are most important during the first 24 hours of evaporation.

As Figure 2 shows, for SOA the contribution of IVOC is always dominant, ranging from 55% after 24 hours to 85% after a month of evaporation. Yields for this mixture are also significant, ranging from 0.06 to 0.2 g-SOA/g-Diesel released.

The procedures and methods here require extensive characterization using GC-SEI-MS or a similar technique, which is currently not widely available. Verification of the model prediction of evaporation indicates that when composition analysis is needed, only the initial composition is required. Because commercial diesel blends appear to be fairly similar, the results here will be good first approximations for all refinery stream diesel blends.

Benefits

The project directly improves the ability to predict the rate of emissions from evaporative sources from very complex mixtures that include material with a wide range of volatilities. The detailed composition of our modeled emissions directly enables prediction of ozone and SOA formation. This model is easily updated as future laboratory experiments reveal new chemistry related to SOA and ozone formation. This model can also be incorporated into existing emissions models written for other computing platforms.

The results of this project directly inform the level of detail needed in emissions inventories and allow a clear assessment of current health risks associated with evaporative emissions. Most notably, we clearly show that evaporative emissions of IVOC are major contributors to both ozone and SOA from evaporative sources that span this volatility range. We are now able to more accurately assess the potential for both ozone and SOA formation from commercial products containing low-vapor pressure VOC or IVOC.

Project Costs

The project utilized the full contracted amount of $106,361 by the SCAQMD. Funds on the order of $1,000,000 from the Gulf of Mexico Research Initiative were used to develop and validate the research strategy.

Commercialization and Applications

The findings of this study are central to future strategies to improve air quality in urban areas. As vehicular emissions continue to be reduced, contributions from sources such as evaporation of complex mixtures like diesel will play a more significant role in pollutant formation. Our results may be applied as updates to emissions models in assessing impacts of evaporative emissions. The evident importance of IVOC emissions over long time periods shows the need for future work analyzing other types of complex mixtures containing material with a wide range of volatilities, such as coatings or solvents.

SCAQMD Contract #13408 **September 2017**

Demonstrate Building Integration of Electric Vehicles, Photovoltaics and Stationary Fuel Cells

Contractor

Advanced Power and Energy Program, UC Irvine

Cosponsors

California Energy Commission (CEC)
South Coast Air Quality Management District

Project Officer

Lisa Mirisola

Background

California's goal to grow the zero emission vehicle (ZEV) market to 1.5 million ZEVs by 2025 will require expanded charging infrastructure since most of these ZEVs will be plug-in electric vehicles (see Executive Order B-16-2012). In fact, limited charging infrastructure is among the barriers that have been cited as preventing wide- scale PEV adoption. Currently, most charging takes place at home, but there is an increasing number of commercial charging stations that are being installed. These stations will address issues of charging access away from home and increase PEV range. As more charging stations are installed at commercial areas, there is a need to develop pricing methods that are attractive to PEV owners and promote the use of newly installed charging infrastructure. Additionally, these pricing methods must also be economical to the owner and integrate with any existing or future distributed generation (DG) technologies.

Project Objective

The objective of this project was to investigate the interactions and optimization of PEV charging in combination with local photovoltaic solar power generation, distributed fuel cell electricity, and utility operation and pricing with goals of:

1) renewable PEV charging, and

2) reliable, transparent, and consistent system operation to facilitate PEV charging.

Technology Description

The technology modeled and demonstrated in this project consists of pricing methodologies for electric vehicle charging to support integrated building operation and distributed generation. Demonstration will occur at the Multi-Purpose Science and Technology Building (MSTB) at UC Irvine.

Status

This project was initiated in October 2013 and was completed in September 2017. Initial delays resulted from delayed installation of the chargers themselves, which occurred in November 2014. Additional delays in the project resulted from competition with other electric vehicle charging stations on the university campus. These charging stations were free, and therefore, attracted all potential customers on the campus. Implementing pricing on these chargers required transfer of ownership to the university since these chargers were a part of a previous research project (Irvine Smart Grid Demonstration). While this represented a delay and limited some of the pricing methodology testing, it reinforced the importance of competition from other lower-priced charging stations.

Figure 1: Demonstration project location

Results

The results from this research project originate from its modeling and demonstration phases. From the modeling phase, the MSTB charging station (6 charger ports) was determined to increase PEV trip feasibility on all-electric miles for a population of 800 vehicles in a scenario with no parking management and 2,000 vehicles in a scenario with a valet-type management. It was also found that in order to minimize utility costs the owner should integrate the building and chargers on the same commercial meter if the maximum demand of the chargers exceeds 20 kW. This is the case for the system installed at the MSTB which has a maximum possible demand of 39.6 kW. The presence of solar PV reduces overall utility costs but it does not change the decision-making process of whether to integrate or separately meter the building and charging load.

Level 3 charging was also investigated and findings indicated that it typically does not provide a benefit to the building by integration and potential tariff changes. The dynamics of a building's electricity consumption have a large effect on overall demand charge cost reductions. A high load factor building provides the least cost reduction potential.

Findings from the demonstration include: strong effect on usage from competition from nearby charging station with free charging; pricing effective in shaping load; pricing also effective in minimizing energy consumption per customer.

Benefits

The potential benefits of utilizing pricing to encourage use of on-site renewable electricity for charging electric vehicles could be significant for GHG emission and pollutant emission reductions. For 1.5 million ZEVs in California, assuming 50% of these within the SCAQMD, a GHG emission reduction potential of 8,370 tons per year (assuming 30 miles average daily travel, 25 mpg, and 100% renewable on-site electricity).

Project Costs

The MSTB charging station was funded by the California Energy Commission ($90,000). The PV system installed was funded by UCI. The SCAQMD funding for this research project to test pricing methods was $150,000.

Commercialization and Applications

The potential market size for these pricing methods is on the order of thousands of charging stations. The pricing strategies investigated here will be applied in another SCAQMD-supported project investigating smart charging of EVs on the UCI Microgrid in collaboration with Kia Motors and Hyundai America Technical Center.

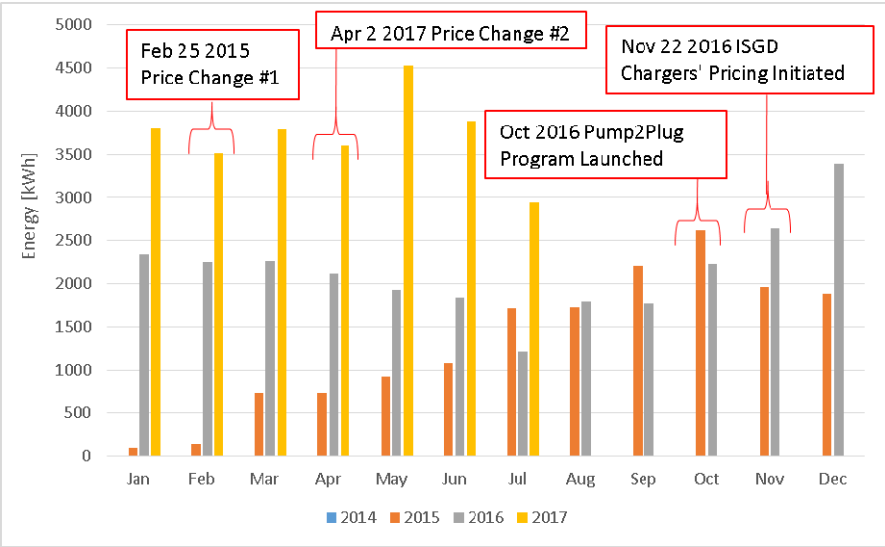

Figure 2: Energy consumption of MSTB charging station during demonstration

SCAQMD Contract #14171 **May 2017**

Study Air Pollution Health Effects on In-Utero Exposure to Traffic-Related Pollutants

Contractor

Southern California Research Center/Allergy and Asthma Associates of Southern California

Cosponsors

British Petroleum (PB)
South Coast Air Quality Management District

Project Officer

Dr. Jean Ospital

Background

This pilot project is one of the first to study the risk of asthma among children from in-utero exposure to in-vehicle traffic-related air pollutants. We also studied traffic-related air pollutants from multiple fixed locations. This study serves to lay the ground work for future investigations and validated analytic tools to be used in the field for further study, it is thus fundamental to the advancement of the study of asthma risk from traffic-related air pollutant exposure in-utero. Additionally, a preliminary finding was that in-utero residential exposure to CALINE4 (a dispersion model for predicting air pollutant concentrations near roadways) traffic-related air pollutants was associated with risk for asthma development but not in-vehicle CALINE4 exposure, despite that in-vehicle exposure was twice as high as residential exposure, which was within EPA standards. Note that residential exposure is far more sustained so cumulative exposure is much higher. This preliminary finding begs further study in the hope of providing recommendations for risk avoidance during pregnancy in order to decrease the development of asthma in children. Moreover, we hope the results of this project will inspire further investigations and funding opportunities in order to better understand the contributing role of traffic-related air pollutant exposure in-utero to the etiology of pediatric asthma.

Project Objective

The aim of this case-control study was to assess the risk of asthma among children living in Orange County from in-utero exposure to traffic-related air pollution.

Technology Description

This pilot project accomplished four tasks in order to study the association of in-utero exposure to traffic-related air pollutants and the risk of developing asthma in children. Particularly important was the development of the field procedures in Task 1 and the experience garnered.

Task 1: Produce an Asthma and Health Outcomes Dataset:

1. Comprehensive participant questionnaire packets were developed.
2. Secure electronic questionnaire packets were designed and implemented.
3. Participants were enrolled:
   a. 5,660 subjects were screened for enrollment.
   b. 533 subjects were enrolled in the study.
   c. 303 subjects completed the study questionnaires.
4. An Asthma and Health Outcomes Datasheet was produced.

Task 2: Estimate traffic-related air pollution exposures at fixed locations:

1. Spatially interpolated monthly concentrations of regionally distributed pollutants (PM_{10}, $PM_{2.5}$, NO_x, NO_2, O_3 and CO) from 1990 to 2013 were used for estimations at fixed locations.
2. A modified Gaussian line source dispersion model (CALINE4) was employed to estimate local traffic-generated air pollutants from traffic emissions.

Task 3: Estimate traffic-related air pollution exposures during times commuting in vehicles:

1. Concentrations were estimated of traffic-related pollutants [polycyclic aromatic hydrocarbon (PAH), particle number

concentration (PNC), NO_x, and $PM_{2.5}$] by roadway type based on our previous work that measured and modeled on-road concentrations of these pollutants.
2. Commuting time of the subjects were obtained by three different measures.
3. Average on-road pollutant concentrations for commuting were calculated by weighting pollutant concentration on each type of road by commuting time spent on the specific road for each individual subject.

Task 4: Evaluate the risk of asthma among children from in-utero exposure to traffic-related air pollution:

1. A case-control study design was used to compare exposures between asthma cases and controls without asthma.
2. Analyses were performed using unconditional logistic regression to model the odds of asthma diagnosis as a function of exposure to traffic-related air pollution near subject homes, work, and commute routes.
3. Models were adjusted for age, socioeconomic status (mother's education level), and the subject's recruitment source.

Status

Project completed in May 2017. Final report on file with complete details of the project.

Results

1. We found no associations of asthma risk with either GIS-estimated commute travel time during pregnancy or questionnaire-reported commute travel time during pregnancy.
2. There were also no associations with modeled in-vehicle exposures during pregnancy with all odds ratios less than 1.00.
3. In univariate models there were positive associations of increased asthma risk from exposure to both ambient residential exposures during pregnancy (except O_3) and CALINE4 traffic-related residential exposures during pregnancy.
4. Estimated daily 24-hour concentrations of $PM_{2.5}$ and PM_{10} at residential locations never exceeded EPA National Ambient Air Quality Standards of 35 µg/m3 and 150 µg/m3, respectively.
5. In-vehicle concentrations were around twice as high for NO_x and $PM_{2.5}$ compared with residential exposures, although this exposure would be for a much shorter duration of time.
6. Multivariate regression models that adjusted for all covariates except age showed that CALINE4 and ambient air pollution variables were still significantly associated with increased risk of asthma from exposure to traffic-related air pollution (NO_2, NO_x, CO).

Benefits

In conclusion, although we found little evidence for an association of asthma risk from air pollution exposure occurring during the pregnancy period, a preliminary finding was that in-utero residential exposure to CALINE4 traffic-related air pollutants was associated with risk for asthma development but not in-vehicle CALINE4 exposure, despite that in-vehicle exposure was twice as high as residential exposure, which was within EPA standards. It is hoped that findings from the present study will inform and energize plans to evaluate asthma risk from in utero air pollution exposure in future studies. Two of the main benefits sited by the study include:

1. Validated analytic tools to study asthma risk from traffic-related air pollutant exposure in-utero, and
2. Improved the understanding of the risk of asthma among children from in-utero exposure to in-vehicle and fixed location exposures to traffic-related air pollutants.

Project Costs

The total project cost was $317,119, on target with the projected budget. Of this, the SCAQMD funded $99,670 and BP funded $217,449 of the total project costs.

Commercialization and Applications

There were no commercial applications yielded by this project.

SCAQMD Contract #15610 **December 2017**

Conduct Engineering Services at SCAQMD Headquarters

Contractor
Goss Engineering, Inc.

Cosponsor
South Coast Air Quality Management District

Project Officer
Patricia Kwon

Background

Goss Engineering, Inc. was hired through a competitive RFP process to provide required engineering services in anticipation of a release of a RFP for installation of EV chargers. The SCAQMD planned to install 92 Level 2 electric vehicle (EV) charging ports at SCAQMD headquarters in Diamond Bar, CA 91765. Goss Engineering prepared construction plans to obtain a permit from the City of Diamond Bar, and assisted with engineering services as required during the installation of EV chargers in 2016-2017.

Project Objective

Goss Engineering assisted in the release of an RFP for installation services by performing the following services: field investigation, 30-day load testing of all electrical panels servicing areas of the parking lot to receive EV chargers, review of as-built drawings for the SCAQMD headquarters facility, preparation of a conceptual engineering design for the entire project, preparation of electrical specifications including sizing of transformers, electrical panels, conduit and wire, preparation of CAD electrical as-built drawings from contractor redlines, and preparation of 90% and 100% construction documents to be submitted to the City of Diamond Bar Plan Check department. Additional services included involvement and standard engineering technical assistance during all phases of construction including coordination of all plan check efforts, participation in the bidder's conference for installation contractors, review of installation bids, provide final punch list, and perform final job walk with SCAQMD staff and installation contractor.

Technology Description

Due to the wide range of cutting edge alternative fuel technologies that are demonstrated at the SCAQMD headquarters facility, even a moderately large scale construction project impacting six areas of the parking lot including upgrade and replacement of three transformers and seven electrical panels presents technical challenges. In addition, there was an inability to shut down power at the facility for even a short 30 minute interval due to the need to have continuous power at the facility for AQMP modeling runs and laboratory analyses for resolving toxics issues at metal processing plants in Paramount. Due to the need to comply with SCAQMD's Rule 1470 (prohibiting use of a backup natural gas generator to provide power during routine maintenance), replacement of the transformer in the main electrical room took place with the power still on through a "hot connect" procedure.

Figure 1: Aerial photo of SCAQMD headquarters denoting areas for EVSE upgrade

Status

Goss Engineering played a critical role in the completion of construction to install 92 Level 2 EV charging ports at SCAQMD headquarters. This project was completed in April 2017.

Results

The engineering services provided at key stages during the EV charger installation project such as the preparation of detailed engineering construction plans to accompany the RFP for installation services and construction documents (and required revisions) to the City of Diamond Bar Plan Check department enabled the construction project to be carried out successfully and with a minimum of delays despite technical challenges, delays in receiving equipment, and unprecedented heavy rainfall.

Figure 2: SCAQMD solar carport featuring upgraded EVSE

The most recent EV charging transaction report shows that there were over 1,329 charging sessions dispensing 15,309 kWh of electricity for EV chargers serving SCAQMD staff, visitors, and the general public.

Benefits

This project showcases the benefits of providing Level 2 charging for EVs at a large workplace to provide the ability for staff, visitors and the general public. On average, SCAQMD staff have a 20 mile one-way commute to work, with some staff having as much as a 45 mile one-way commute. Without workplace charging, staff would be unable to drive their EVs to work and be able to return home. This results in increased zero emission vehicle miles traveled, particularly during critical morning and evening commuting hours when congestion impacts are at their greatest.

Project Costs

Total project costs were $60,000, all funded by the SCAQMD from the Clean Fuels Fund. The initial contract was $50,000, with an additional $10,000 added through an amendment to cover unanticipated site plan and permitting expenses. Specifically, permitting requirements which were not anticipated included a site survey to address American with Disabilities Act requirements and a short circuit study to address National Electrical Code requirements.

Commercialization and Applications

The utilization of engineering services to define the installation phase of the project assisted greatly in allowing the installation to stay within budget and to be completed within the desired time frame. It is recommended that for the installation of workplace charging at large facilities such as SCAQMD headquarters that an engineering firm be available to provide the necessary technical assistance at key points during the project. In particular, engineering services were critical to define the load of existing panels and ensure proper specifications and upsizing of transformers, panels, conduit and wiring. This upsizing incorporated not only the planned installation of 92 EV charging ports but also anticipated future deployments of EV chargers that were likely to occur within the next 5-10 years to future proof the facility. This future proofing enabled staff to later serve as a site host for a new 50 kW DC fast charger with CHAdeMO and CCS connectors at the front lobby parking area to better serve EVs capable of fast charging.

Appendix D

Project Ranking

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Project Ranking

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 the proposed ranking 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. As a part of the 2016 AQMP, staff has also included the Draft Financial Incentives Funding Action Plan to address the funding necessary for full implementation of the control measures included.

Staff has proposed a simplified approach to ranking the core technologies, especially some of the specific platforms and technologies discussed in the draft plan and annual report. The rankings below take into account 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 "Consumer Reports" type approach:

● Excellent ◓ Good ○ Satisfactory ◒ Poor • Unacceptable

The table below summarizes staff ranking of the potential projects anticipated in the draft plan, 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
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
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
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
EV—electric vehicle
EVSE-electric vehicle supply equipment
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
GDI—gasoline direct injection
GGE—gasoline gallon equivalents
GGRF—Greenhouse Gas Reduction Relief Fund
GHG—Greenhouse Gas
GNA—Gladstein, Neandross & Associates, LLC
GTL—gas to liquid
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
HDV—heavy-duty vehicle
HEV—Hybrid electric vehicle
HOA—Homeowners Association

LIST OF ACRONYMS (cont'd)

HQSA—hydrogen quality sampling adapter
HPDI—High Pressure Diesel Injection
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
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
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
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
RDD&D (or RD3)—research, development, demonstration and deployment
REC—renewable energy certificates
RFP—Request for Proposal
RFS—renewable fuel standards
RI—reactive intermediates
RNG—renewable natural gas
RPS—Renewable Portfolio Standard
RRC—rolling resistance co-efficient

LIST OF ACRONYMS (cont'd)

RTA—Riverside Transit Agency
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
TSI—Three Squares, Inc.
TTSI-Total Transportation Services, Inc.
TWC—three-way catalyst
UCR—University of California Riverside
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
WVU—West Virginia University
ZECT—Zero Emission Cargo Transport
ZEV—zero emission vehicle

South Coast Air Quality Management District

21865 Copley Drive, Diamond Bar, CA 91765-4178 • Tel 909 396 2000 • 800 CUT SMOG • www.aqmd.gov