Technology Advancement Office

Leading the way to zero and near-zero emission technologies

Clean Fuels Program 2015 Annual Report and 2016 Plan Update

March 2016

South Coast Air Quality Management District
aqmd.gov

South Coast Air Quality Management District

Governing Board

Chairman

William A. Burke, Ed.D.
Assembly Speaker Appointee

Vice Chairman

Ben Benoit
Councilmember, City of Wildomar
Riverside County Cities

County Representatives

Michael D. Antonovich
Supervisor, Los Angeles County

John J. Benoit**
Supervisor, Riverside County

Shawn Nelson
Supervisor, Orange County

Janice Rutherford*
Supervisor, San Bernardino County

State Representatives

Joseph K. Lyou, Ph.D.
Governor's Appointee

Dr. Clark E. Parker, Sr.
Senate Rules Committee Appointee

Cities Representatives

Joe Buscaino*
Councilmember, City of Los Angeles
City of Los Angeles

Michael Cacciotti
Councilmember, City of South Pasadena
Los Angeles County, Eastern Region

Larry McCallon*
Mayor, City of Highland
San Bernardino County Cities

Judith Mitchell*
Councilmember, City of Rolling Hills Estates
Los Angeles County, Western Region

Dwight Robinson*
Councilmember, City of Lake Forest
Orange County Cities

Acting Executive Officer
Michael B. O'Kelly

*Technology Committee Members **Technology Committee Chairman

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
Lourdes Cordova Martinez, Community Relations Manager

Al Baez, Program Supervisor
Brian Choe, Program Supervisor
Connie Day, Program Supervisor
Ranji George, Program Supervisor
Joseph Impullitti, Program Supervisor
Lisa Mirisola, Program Supervisor
Vicki White, Program Supervisor

Jason Aspell, Sr. Air Quality Engineer

Vasken Yardemian, Sr. Staff Specialist

Walter Shen, Staff Specialist

Mark Coleman, Air Quality Specialist
Patricia Kwon, Air Quality Specialist
Von Loveland, Air Quality Specialist
Krystle Martinez, Air Quality Specialist
Ashkaan Nikravan, Air Quality Specialist
Greg Ushijima, Air Quality Specialist

Mei Wang, Air Quality Specialist
Andrew Yoon, Air Quality Specialist
Greta Grier, Air Quality Inspector II
Arun Kumar, Air Quality Inspector II

Drue Hargis, Sr. Public Information Specialist

Penny Shaw Cedillo, Sr. Administrative Secretary
Pat Krayser, Senior Administrative Secretary
Ana Ponce, Sr. Administrative Secretary
Marjorie Eaton, Secretary
Donna Vernon, Secretary
Lani Montojo, Staff Assistant
Michelle White, Staff Assistant
Benigna Taylor, Contracts Assistant
Ana Troccoli, Contracts Assistant
Deanna Doerr, Senior Office Assistant

Other Staff Contributors
Henry Hogo, Assistant Deputy Executive Officer, Mobile Sources
Dean Saito, On-Road Mobile Source Manager
David Coel, Program Supervisor
Michael Krause, Program Supervisor
Adewale Oshinuga, Program Supervisor
Philip Barroca, Air Quality Specialist
Lori Berard, Air Quality Specialist
Richard Carlson, Air Quality Specialist
Wei Li, Air Quality Specialist

Table of Contents

EXECUTIVE SUMMARY EX-1

Background & Overview 1

Program Background 1
Program Review 1
The Need for Advanced Technologies & Clean Fuels 2
Program Funding 6
2015 Overview 7
Core Technologies 7

Barriers, Scope and Impact 13

Overcoming Barriers 13
Scope and Benefits of the Clean Fuels Program 13
Strategy and Impact 15
Research, Development and Demonstration 16
Technology Deployment and Commercialization 20

2015 Funding & Financial Summary 27

Funding Commitments by Core Technologies 27
Review of Audit Findings 28
Project Funding Detail by Core Technologies 29
Project Summaries by Core Technologies 35
Electric/Hybrid Technologies 35
Hydrogen and Mobile Fuel Cell Technologies and Infrastructure 41
Engine Systems 46
Fueling Infrastructure & Deployment (NG/RNG) 47
Fuels/Emissions Studies 48
Emission Control Technologies 50
Outreach & Technology Transfer 51

Progress and Results in 2015 57

Key Projects Completed 57

2016 Plan Update 67

Overall Strategy 67
Funding Scope 68
Core Technologies 70
Target Allocations to Core Technology Areas 76

Program Plan Update For 2016 79

Funding Summary of Potential Projects 79
Technical Summaries of Potential Projects 83
Electric/Hybrid Technologies & Infrastructure 83
Hydrogen and Fuel Cell Technologies & Infrastructure 89
Engine Systems 94
Fueling Infrastructure and Deployment (NG/RNG) 96
Fuels/Emission Studies 99
Stationary Clean Fuel Technologies 104
Emission Control Technologies 107
Health Impacts Studies 109
Outreach and Technology Transfer 112

Appendix A
Technology Advancement Advisory Group A-1
SB 98 Clean Fuels Advisory Group A-2

Appendix B

Open Clean Fuels Contracts as of January 1, 2016 ..... B-1

Appendix C

Final Reports for 2015 ..... C-1

Appendix D

Acronyms D-1

Figures

Figure 1: NOx Emission Reductions Needed as Projected in Preliminary 2016 AQMP 3
Figure 2: 2023 NOx Contributors by Sector 4
Figure 3: Directly Emitted 2023 PM2.5 Emissions (65 tons per day) 4
Figure 4: Stages of Clean Fuels Program Projects 14
Figure 5: TransPower Electric Drive Drayage (EDD) Trucks 17
Figure 6: Drayage Truck Connected to Demonstration Catenary System in Carson 18
Figure 7: ISL-G Near-Zero Natural Gas Engine 19
Figure 8: Truck with ISL-G-NZ Ultra Low-NOx Engine 19
Figure 9: UCR's 4 MWs of Photovoltaic Panels Constructed for SIGI 21
Figure 10: Residential Level 2 EV Charger 21
Figure 11: Existing Level 2 Chargers under SCAQMD's Solar Carport 22
Figure 12: Hydrogen Infrastructure Rollout in the SCAQMD 23
Figure 13: La Canada Flintridge Retail Hydrogen Station, Located at Arco Gas Station 23
Figure 14: West Los Angeles Retail Hydrogen Station, Located at Chevron Gas Station 24
Figure 15: Torrance Retail H2 Station, Located at Shell Gas Station 24
Figure 16: Orange County Sanitation District Non-Retail H2 Station, Located w/CNG Station 25
Figure 17: Distribution of Funds for Executed Clean Fuels Projects CY 2015 ($10.7 million) 28
Figure 18: Volvo's PHEV Drayage Truck 58
Figure 19: ISX12 G Beta Engine 58
Figure 20: Trucks Used in Demonstration 59
Figure 21: Test Routes for Phase I Study 59
Figure 22: Distance-Specific NOx Emissions from the 7 Test Vehicles 60
Figure 23: NOx and NH3 reduction efficiency results for varying temperature bins… 61
Figure 24: UCI's CCHP System with Absorption Chiller Design 62
Figure 25: Projected Cost Distribution for Potential SCAQMD Projects in 2016 ($16.4M) 77

Tables

Table 1: NOx Summer Planning Inventory - 2012 to 2023 3
Table 2: SCAQMD Major Funding Partners in CY 2015 16
Table 3: Contracts Executed or Amended (w/$) between January 1 & December 31, 2015 30
Table 4: Supplemental Grants/Revenue Received into the Clean Fuels Fund (31) in CY 2015 33
Table 5: Summary of Federal & State Funding Awarded between Jan. 1 & Dec. 31, 2015 33
Table 6: Projects Completed between January 1 & December 31, 2015 63
Table 7: Summary of Potential Projects for 2016 81

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. Recognizing this challenge, in 1988 the state established the SCAQMD's Clean Fuels Program (Program), along with the SCAQMD's Technology Advancement Office (TAO). The Clean Fuels Program affords the SCAQMD the ability to fund the development, demonstration and accelerated deployment of clean fuels and transportation technologies.

For over 20 years, 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), is its implementation as a public-private partnership in conjunction with private industry, technology developers, academic institutions, research institutions and government agencies. Further, while the SCAQMD aggressively seeks leverage funds to accomplish more with every dollar, it also strives to act as a leader in technology development and commercialization in an effort to accelerate the reduction of criteria pollutants. As a result, the SCAQMD 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 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 expenditures for the next CY, essentially re-calibrating the technical direction 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 2016 Plan Update, along with the 2015 Clean Fuels Annual Report, which are due to the Legislative Analyst by March 31, 2016.

The overall strategy of the SCAQMD's Clean Fuels Program is based in large part on technology needs identified through the Air Quality Management Plan (AQMP) process and the SCAQMD Board's directives to protect the health of residents in Southern California, which encompasses approximately 16.8 million people (nearly half the population of California). The AQMP is the long-term "blueprint" that defines:

- basin-wide emission reductions needed to achieve federal ambient air quality standards;
- regulatory measures to achieve those reductions;
- timeframes to implement these proposed measures; and
- technologies required to meet these future proposed regulations.

The preliminary 2016 AQMP control measures 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 air quality standards. The preliminary 2016 AQMP

projects that an approximate 50 percent reduction in NOx is required by 2023 and a 65 percent reduction by 2031, the majority of which must come from mobile sources both on- and off-road. These emission reduction needs were further identified in the California Air Resources Board's (CARB's) recent draft discussion document "Mobile Source Strategy" (October 2015)[1]. Moreover, the SCAQMD is currently only one of two regions in the nation recognized as an extreme ozone nonattainment area (the other is San Joaquin Valley). Ozone (a key component of smog) is created by a chemical reaction between NOx and volatile organic compound (VOC) emissions at ground level. This is especially noteworthy because the largest contributor to ozone is NOx emissions, and mobile sources contribute approximately 80 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 in size as contained in a cubic meter of air, expressed as micrograms per cubic meter ($\mu g/m^3$).

The preliminary 2016 AQMP includes integrated strategies and measures to demonstrate attainment of the following NAAQS:

- 8-hour Ozone (75 parts per billion or ppb) by 2031
- Annual PM2.5 (12 $\mu g/m^3$) by 2021-2025
- 8-hour Ozone (80 ppb) by 2023 (updated from the 2012 AQMP)
- 1-hour Ozone (120 ppb) by 2022 (updated from the 2012 AQMP)
- 24-hour PM2.5 (35 $\mu g/m^3$) by 2019 (updated from the 2012 AQMP)

The 2016 AQMP will also take an initial look at the emission reductions needed to meet the new federal 8-hour ozone air quality standard of 70 ppb anticipated to be attained by 2037.

The daunting challenge to reduce NOx and PM2.5 requires the Clean Fuels Program to encourage and accelerate advancement of transformative fuel and transportation technologies, leading the way for commercialization of progressively lower-emitting fuels and vehicles. Given the relationship between NOx, ozone and PM2.5, the 2016 Plan Update must emphasize emission reductions in all these areas. However, the confluence of federal, state and local planning efforts on climate change, greenhouse gases (GHGs), petroleum reduction, air quality and other environmental areas should provide co-benefits that may help the region.

Since the last AQMP, it has become clear that the effect of moving containers through the Ports of Los Angeles and Long Beach and the subsequent movement of goods throughout the region not only have a dramatic impact on air quality but also the quality of life in the communities along the major goods movement corridors. 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, such as electric trucks, plug-in hybrid trucks with all-electric range, zero emission container transport technologies, trucks operating from wayside power including catenary technology and other heavy-duty technologies. The SCAQMD goods movement projects that have been initiated or anticipated incorporate a variety of fuels, including electricity, natural gas, biofuels, hydrogen and diesel. The prioritization of these types of projects is emphasized in this 2016 Plan Update.

The proposed funding allocations and prioritization are commensurate with the emissions inventory for the various categories, as illuminated by Table 1 (page 3) which reflects NOx summary planning inventory in tons per day (tpd) from base year 2012 to NOx inventory for 2023, as projected in the preliminary 2016 AQMP.

[1] http://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc_dd.pdf

2015 Annual Report

During CY 2015 the SCAQMD executed 69 new contracts, projects or studies and modified 9 continuing projects adding additional dollars toward research, development, demonstration and deployment (RDD&D) of alternative fuel and clean fuel technologies. Table 3 (page 30) lists these 78 projects or studies, which are further described in this report. The SCAQMD Clean Fuels Program contributed nearly $10.7 million in partnership with other governmental organizations, private industry, academia and research institutes, and interested parties, with total project costs of nearly $47.3 million. Table 4 (page 33) provides information on outside funding received into the Clean Fuels Fund ($2.75 million in 2015) as cost-share passed through the SCAQMD for the contracts executed in CY 2015. Table 5 (page 33) provides a comprehensive summary of federal, state and other revenue awarded to the SCAQMD during CY 2015 (approximately $8.56 million) for projects to be included within the Clean Fuels Program or which align well with and are complementary to the Clean Fuels Program.

The projects or studies executed in 2015 addressed a wide range of issues and opportunities with a diverse mix of advanced technologies. The following core areas of technology advancement for 2015 executed contracts (in order of funding percentage) include:

- Engine Systems (emphasizing alternative and renewable fuels for truck and rail applications)
- Electric and Hybrid Vehicle Technologies and Related Infrastructure (emphasizing electric and hybrid electric trucks and container transport technologies with zero emission operations)
- Hydrogen and Mobile Fuel Cell Technologies and Infrastructure
- Outreach and Technology Transfer
- Fuels and Emission Studies
- Emission Control Technologies
- Fueling Infrastructure and Deployment (predominantly natural gas and renewable fuels)

During CY 2015, the SCAQMD supported a variety of projects and technologies, ranging from near-term to long-term research, development, demonstration and deployment activities. This "technology portfolio" strategy provides the 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 executed in CY 2015 included but are not limited to continued development and demonstration of electric and hybrid technologies with an emphasis on zero emission goods movement technologies, development and demonstration of hydrogen technologies and infrastructure, development and demonstration of heavy-duty natural gas engines and vehicles, and fuels and emissions studies.

As of January 1, 2016, there were 112 open contracts (Appendix B) in the Clean Fuels Program.

Forty RDD&D projects or studies and seven technology assessment and transfer contracts were completed in 2015, as listed in Table 6 (page 63). Appendix C comprises two-page summaries of the technical projects completed in 2015. In accordance with California Health and Safety Code Section 40448.5.1(d), this report must be submitted to the state legislature by March 31, 2016, after approval by the SCAQMD Governing Board.

2016 Plan Update

Every year TAO staff re-evaluates the Clean Fuels Program to develop a Plan Update which essentially serves to re-assess 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 opportunity. As the state and federal governments have turned a great deal of their attention to climate change and

petroleum reduction goals, the 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) and petroleum reductions. Due to these "co-benefits," the SCAQMD has been successful in partnering with the state and federal government, which allows the Clean Fuels Program to extensively leverage its funding.

The overall strategy is based in large part on technology needs identified in the SCAQMD's AQMP and the SCAQMD Governing Board's directives to protect the health of residents in the Basin. As summarized in Figure 1 (page 3), the NOx, VOC and PM emission sources of greatest concern are heavy-duty on-road vehicles, medium- and light-duty on-road vehicles, and off-road equipment.

To identify project or technology opportunities in which its available 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 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 issuance of Requests for Information to determine the state of various technologies and the challenges faced by those technologies for commercialization.

The Plan Update includes projects to develop, demonstrate and commercialize a variety of technologies, from near-term to long-term, that are intended to provide solutions to the emission control needs identified in the preliminary 2016 AQMP. As noted, the preliminary 2016 AQMP analysis indicates that an approximate 50 percent reduction in NOx is required by 2023 with an additional 15 percent NOx reduction beyond 2023 levels by 2031. Given the need for these significant reductions over the next 7-15 year timeframe, mid- and longer-term alternative fuels, hybrid, electric and fuel cell based technologies are emphasized. Several of the technology 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;
- mitigating criteria pollutant increases from renewable fuels, such as renewable diesel and dimethyl ether (DME);
- developing electric, hybrid, battery and plug-in hybrid technologies across light-, medium- and heavy-duty platforms; and
- producing transportation fuels and energy from renewable sources.

Table 7 (page 81) lists the potential projects across the nine core technologies identified in this report. Potential projects for 2016 total $16.4 million, with anticipated leveraging of more than $3 for every $1 of Clean Fuels funding for total project costs of more than $66 million. 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 & 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. Due to these challenges, the state legislature enabled the SCAQMD to implement the Clean Fuels Program to accelerate the implementation and commercialization of clean fuels and advanced technologies. In 1999, state legislation was passed which amended and extended 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 panel of external experts that helps review the Clean Fuels Program.

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 approval of the required annual report prior to submittal to the SCAQMD Governing Board. Also in 1999, in light of the formation of the 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 2015 Annual Report and 2016 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 least two full-day retreats of the two Advisory Groups, typically in the summer and winter, review by other technical experts, review by the Technology Committee of the SCAQMD Governing Board, a public hearing of the Annual Report and Plan Update before the full SCAQMD Governing 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 finally submittal of the 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. Table 1 reflects NOx inventory in the 2012 base year and NOx inventory as projected by attainment year 2023, due to continued implementation of already adopted control measures. The need for advanced technologies and clean fuels is best illustrated by Figure 1 below, which identifies NOx emissions by category and identifies just how far those emissions must be reduced to meet federal standards by 2023 and 2031. The italicized source categories in Table 1 are the primary focus of the Clean Fuels Program.

Table 1: NOx Summer Planning Inventory - 2012 to 2023

2012 (base year)		2023 (without further control measures)	
Source Category	**NOx (tpd)**	**Source Category**	**NOx (tpd)**
HD Diesel Trucks	150	*HD Diesel Trucks*	45
Cars/Light-Duty Trucks/SUVs	82	*Off-Road Equipment*	45
Off-Road Equipment	76	*Ocean Going Vessels*	23
Ocean Going Vessels	30	*Locomotives*	23
Medium Duty Trucks	27	*Cars/Light-Duty Trucks/SUVs*	22
Buses	25	*Aircraft*	16
Locomotives	21	RECLAIM	15
RECLAIM	20	*Commercial Harbor Craft*	11
Commercial Harbor Craft	17	Manufacturing and Industrial	10
Residential Fuel Combustion	14	Residential Fuel Combustion	9
Aircraft	13	Service and Commercial	9
Service and Commercial	12	*Buses*	8
Manufacturing and Industrial	12	*Medium Duty Trucks*	8
Heavy Duty Gas Trucks	11	*Recreational Boats*	6
Recreational Boats	8	*Heavy Duty Gas Trucks*	5
All Other Sources	9	All Other Sources	10
	529		**265**

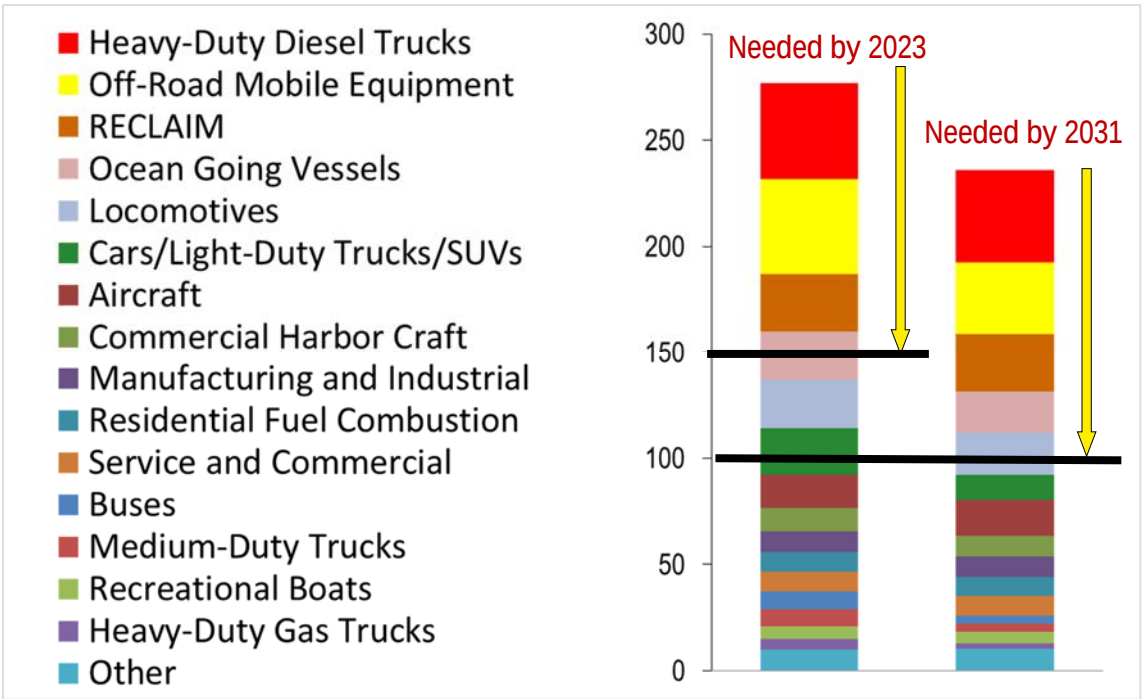


Figure 1: NOx Emission Reductions Needed as Projected in Preliminary 2016 AQMP[2]

[2] ***Data used to generate the table and chart above are from an inventory run on 1/7/16.***

Additionally, the following piechart reflects NOx contributors by sector, sharply illustrating the impact of mobile sources on air quality and why the preliminary 2016 AQMP calls for an approximate 50 percent reduction of NOx by 2023 as well as why this region is recognized as an extreme ozone nonattainment area.

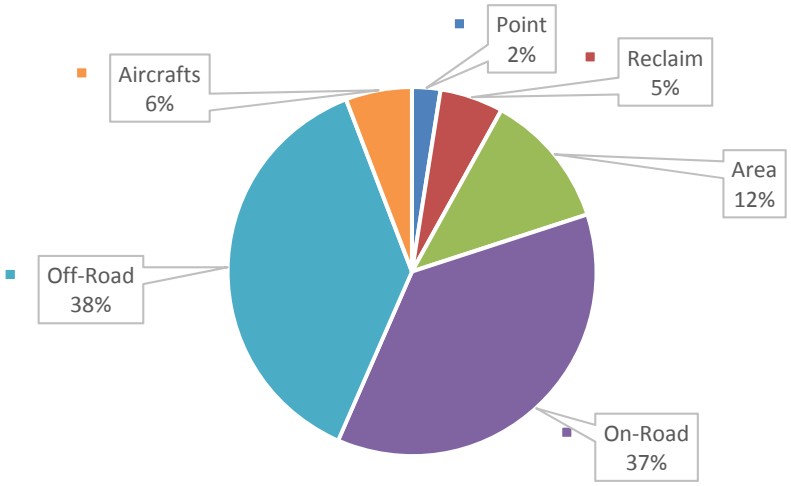


Figure 2: 2023 NOx Contributors by Sector

Finally, the following piechart reflects the relative contribution of directly emitted PM2.5 by source category to the 2023 emission inventory for an average annual day and does not include PM2.5 from secondary organic aerosols (SOAs) that may be generated as a result of emissions from on- and off-road equipment. A supplement to the 24-hour PM2.5 SIP will address further PM reductions to achieve attainment since the 24-hour PM2.5 standard was not attained in 2014 due to extreme drought conditions.

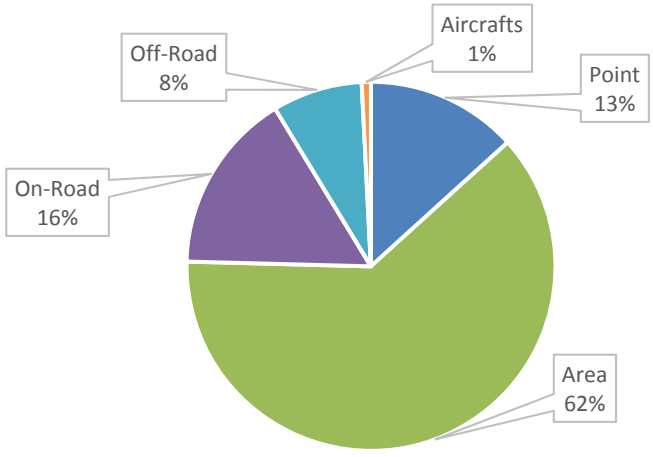


Figure 3: Directly Emitted 2023 PM2.5 Emissions (65 tpd)

To fulfill long-term emission reduction targets, the preliminary 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. Environmental Protection Agency (U.S. EPA) in 1997 and 2006, are projected to require additional long-term control measures for both NOx and VOC. The preliminary 2016 AQMP's estimate of needed NOx reductions will require the SCAQMD Clean Fuels Program to encourage and accelerate advancement of cleaner, transformative transportation technologies that can be used as control strategies in the AQMP.

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, initially launched in 2012, 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 early January 2015, Governor Brown's state-of-the-state address included ambitious goals to help meet California climate targets for 2030 and beyond, including increasing the amount of electricity generated from renewable sources from 33 to 50 percent and reducing the use of petroleum in cars and trucks by up to 50 percent from today's levels. Subsequently, in October 2015, the Governor signed SB 350 (De León) to codify the goals outlined in his January 2015 inaugural address, albeit prior to signature it was amended to remove the 50 percent reduction of petroleum use in cars and trucks. Nonetheless, SB 350 will still dramatically reshape California's energy economy. In July 2015 the Governor also issued an Executive Order to develop a California Sustainable Freight Action Plan to improve freight efficiency and transition to zero emission technologies.

The emission reductions needed for this region are outlined further in CARB's recent draft discussion document "Mobile Source Strategy" (October 2015)[3]. Specifically, the document 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 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. 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

[3] http://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc_dd.pdf

technologies into the fleet, requiring cleaner 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.

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 Governing Board continues to aggressively carry out the Clean Fuels Program and promote alternative fuels through its Technology Advancement Office (TAO).

The Clean Fuels Program is intended to assist in the rapid 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 2015 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 previous cap of two-and-half percent.

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 2015 the funds available through each of these mechanisms were as follows:

- Mobile sources (DMV revenues) $13,001,831
- Stationary sources (emission fee surcharge) $332,791

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 4 (page 33) lists supplemental grants and revenues totaling $2.75 million for contracts executed in CY 2015. Table 5 (page 33) lists federal and state revenue totaling nearly $8.6 million awarded to the SCAQMD in 2015 for projects that will be part of the Clean Fuels Program or align well and will 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 2015, the Clean Fuels Program leveraged each $1 to approximately $4 of outside funding. 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 act as a leader in technology development and commercialization in an effort to accelerate the reduction of criteria pollutants. 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 2015 are listed in Table 2 (page 16).

2015 Overview

This report summarizes the progress of the SCAQMD Clean Fuels Program for CY 2015. 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 2015. During the period between January 1 and December 31, 2015, the SCAQMD executed 69 new contracts, projects or studies and modified 9 continuing projects adding additional dollars during CY 2015 that support clean fuels and advanced zero, near-zero and low-emission technologies. The SCAQMD Clean Fuels Program contribution for these projects was approximately $10.7 million, inclusive of $2.75 million received into the Clean Fuels Fund as cost-share for contracts executed in this reporting period, with total project costs of nearly $47.3 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 4, page 33), 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 ($8.56 million in 2015, see Table 5). More details on this financial summary can be found later in this report. The SCAQMD will continue to pursue federal and state funding opportunities in 2016 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 acting as 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:

- Electric and Hybrid Vehicle Technologies and Infrastructure (emphasizing electric and hybrid electric trucks and container transport technologies with zero emission operation)
- Hydrogen and Fuel Cell Technologies and Infrastructure
- Engine Systems (emphasizing heavy-duty alternative and renewable fuel engines for truck and rail applications)
- Fueling Infrastructure and Deployment (predominantly natural gas and renewable fuels)
- Health Impacts, Emissions and Fuel Studies
- Stationary Clean Fuels Technologies
- Emission Control Technologies
- Outreach and Technology Transfer

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 turned a great deal of their attention to climate change, the 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. The ultimate challenge for the SCAQMD is to identify project or technology opportunities in which its available funding can make a difference in achieving progressively cleaner air in the Basin. To do this, the SCAQMD employs a number of outreach and networking activities. These 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 Technology Advancement Office 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 2016 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 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.

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 consistency with program goals and funding constraints. The core technologies for the SCAQMD programs that meet both the funding constraints as well as preliminary 2016 AQMP needs for achieving clean air are briefly described below.

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. At the federal level, there is also the continued push for PEVs through the EV Everywhere Program.

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, 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., 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. Electric and hybrid technologies are also being explored to address one of the SCAQMD's 2015-16 Goals and Priority Objectives, which is to continue development and demonstration of zero-emission goods movement technologies.

While EV adoption has surpassed 184,000 vehicles in California, according to the PEV Collaborative, there is still a need for charging infrastructure in order to achieve the fleet penetration required for clean air. The CPUC recently approved 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.

Hydrogen and Mobile Fuel Cell Technologies and Infrastructure

Toyota and Hyundai have commercialized light-duty fuel cell vehicles in 2015, Honda announced plans to introduce a fuel cell vehicle in 2016, and numerous others have plans to commercialize

their own in the near future. The greatest challenge 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 51 stations funded by CEC by the end of 2015, six non-retail and six retail were operational, but all 51 are expected to be operational by the end of 2016 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. Their July 2015 findings report that there were 179 fuel cell vehicles registered in California, a 43% growth from 2013 estimates, with CEC indicating there this number should grow to 300 by the end of 2015. However, CARB surveys of automakers project 10,500 fuel cell vehicles in California by the end of 2018 and 34,300 by the end of 2021. Clearly, the SCAQMD must continue to support the infrastructure required to refuel the demonstration fuel cell vehicles, but is also actively engaged in finding alternatives to the costly and potential longer term fuel cell power plant technology. As mentioned previously, plug-in hybrid technology could help enable fuel cells by reducing the capacity, complexity and cost of the fuel cell vehicle system.

Engine Systems

Medium- and heavy-duty on-road vehicles contributed approximately 33 percent of the Basin's NOx based on preliminary 2016 AQMP data. More importantly, on-road heavy-duty diesel trucks account for 33 percent of the on-road mobile source PM2.5, which has known toxic effects. These figures notably do not include the significant contribution from off-road mobile sources, which emit 155 tons per day of NOx and 7.9 tons per day of 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 diesel and potentially other renewable liquid fuels such as dimethyl ether (DME), 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. The SCAQMD's FY 2015-16 Goals and Priority Objectives also includes development and demonstration of next-generation natural gas engines/hybrid vehicles with the goal of developing engines 75-90 percent cleaner than the current emissions standard for NOx. Additionally, options for integrating with hybrid systems and alternative fuels need to be explored to provide additional NOx reductions.

Fueling Infrastructure and Deployment

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. 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.

Health Impacts, Emissions and Fuel 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.

Recently, the SCAQMD funded a study to evaluate PM2.5 formation from gasoline direct injection (GDI) engines and from varying ethanol blends to better understand the chemical composition of PM and health impacts of PM from a wider variety of fuels and vehicle technologies. The results from this study are expected to provide important information about the potential impacts of mid-level and high-level ethanol and iso-butanol blends on emissions and air quality during the near- and medium-term implementations of renewable fuel regulations, including assessing the health consequences of population exposure to GDI light-duty vehicle traffic sources in Southern California.

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.

Outreach and Technology Transfer

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.

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 conventional 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 4 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.

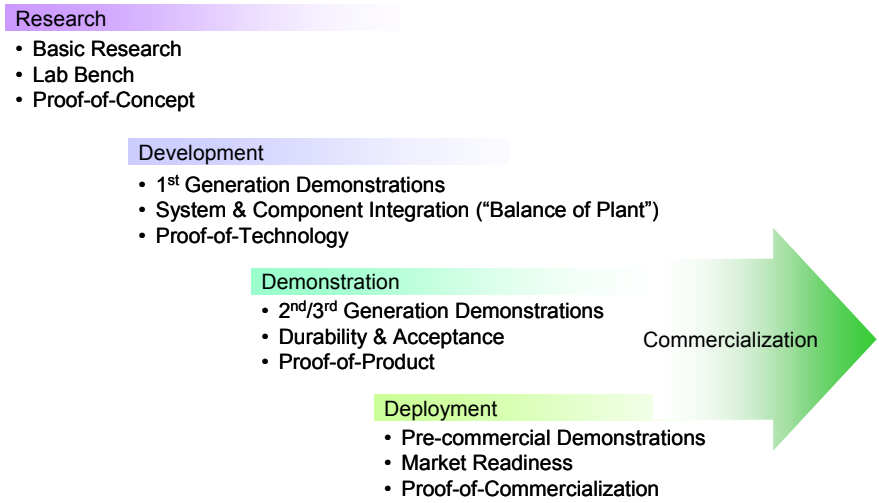


Figure 4: Stages of Clean Fuels Program Projects

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
- Emission Solutions: 7.6L (NG)
- Cummins Westport: low-NOx natural gas ISL G 8.9L engines (0.2 & 0.02 g/bhp-hr)
- Westport Power: ISX 15L (LNG), Westport GX 15 L (dual fuel)
- Detroit Diesel: Series 60G (CNG/LNG), Series 50G (CNG/LNG);
- John Deere: 6068 (CNG), 6081 (CNG);
- Mack: E7-400G (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);
- 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); and
- 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).

- Electric and Hybrid Electric Vehicle Development and Demonstrations
  - EPRI hybrid vehicle evaluation study;
  - Hybrid electric vehicle demonstrations with SCE, UC Davis and AC Propulsion;
  - 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;
  - LACMTA battery electric buses;
  - Electric school buses with V2G capability; and
  - TransPower battery electric heavy-duty truck and yard hostlers.
- Aftertreatment Technologies for Heavy-Duty Vehicles
  - Johnson Matthey and Engelhard trap demonstrations on buses and construction equipment; and
  - Johnson Matthey SCRT and SCCRT NOx and PM reduction control devices on heavy-duty on-road trucks.

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 (pages 1-2), 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 U.S. DOE and several of its 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 Plug-In Electric Vehicle (PEV) Collaborative, the California Hydrogen Business Council (CHBC) the Electric Power Research Institute (EPRI), the Electric Drive Transportation Association (EDTA), the SoCalEV Collaborative, the West Coast Collaborative, which is part of the National Clean

Diesel Campaign, and the Transportation Research Board. 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 2015 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. Such partnerships are essential to address commercialization barriers and to help expedite the implementation of advanced low emission technologies. Table 2 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 2014 Project Summaries (beginning page 35) contained within this report.

Table 2: SCAQMD Major Funding Partners in CY 2015

Research Funding Organizations	Major Manufacturers/Providers
California Air Resources Board	Cummins Inc.
California Energy Commission	Cummins Westport, Inc.
National Renewable Energy Laboratory	Ports of Los Angeles & Long Beach
U.S. Department of Energy	Gas Technology Institute
U.S. Environmental Protection Agency	Southern California Gas Company
	University of California Riverside/ CE-CERT
	Other California Universities (Irvine, LA, San Diego)
	US Hybrid Corporation
	Toyota

The following two subsections broadly address the SCAQMD's impact and benefits by describing specific examples of accomplishments and commercial—or near-commercial—products supported by the Clean Fuels Program in CY 2015. 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 include: (a) development and demonstration of zero emissions goods movement technologies; and (b) development, integration and demonstration of ultra-low emission natural gas engines for heavy-duty vehicle applications.

Develop and Demonstrate Zero Emissions Goods Movement Technologies System

Heavy-duty diesel trucks in the South Coast Air Basin remain a significant source of emissions with adverse health impact, especially in the surrounding communities along the goods movement corridors near the Ports of Los Angeles and Long Beach and next to major freeways. In order to mitigate the impact and attain stringent federal ambient air quality standards for the

region, SCAQMD has been aggressively promoting and supporting the development and deployment of advanced zero emission cargo transport technologies, in partnership with the Southern California Regional Zero Emission Truck Collaborative, comprised of the Los Angeles Metropolitan Transportation Authority, the Ports of Los Angeles and Long Beach, the Southern California Association of Governments, and the Gateway Cities Council of Governments.

Figure 5: TransPower Electric Drive Drayage (EDD) Trucks

With a grant from the DOE's Zero Emission Cargo Transport (ZECT) Program in 2012, the SCAQMD has been working with Transportation Power (TransPower) and US Hybrid, locally based EV system integrators, to develop Class 8 battery electric trucks (BETs) for demonstration in real-world drayage operations to evaluate the trucks' performance and durability to support demanding drayage duty cycles. To date, TransPower has completed and deployed four BETs in field demonstration with drayage fleets at the Ports of Los Angeles and Long Beach, including Total Transportation Services and California Cartage Company. With an estimated range of 80–100 miles, these BETs are deployed in near-dock and local operations within a 20-mile radius from the Ports and have been providing dependable service with positive feedback from fleet drivers on its quiet and smooth operations. US Hybrid is currently on-road testing their first BET with a plan to deploy it in drayage service in early 2016.

Building on the success of the ZECT project, SCAQMD applied for and received a $9.75 million grant from the DOE in 2014 to demonstrate additional electric drayage truck technologies. This project, termed ZECT II, launched in 2015 and involves development and demonstration of five different electric truck platforms, consisting of three fuel cell electric trucks and two types of plug-in hybrid electric trucks (PHETs) as follows:

- BAE Systems will develop a battery electric truck with a hydrogen fuel cell range extender leveraging the expertise of BAE Systems and Ballard Power Systems to test their hybrid electric fuel cell propulsion system, currently used for transit buses, in drayage applications. The truck will have 30 kg of hydrogen on-board to provide approximately 110 miles of range per fueling.

- TransPower will develop two battery electric trucks with hydrogen fuel cell range extenders. These trucks will utilize TransPower's proven ElecTruck drive system with a small fuel cell to provide approximately 150 miles of range. One truck will be equipped with a 30 kW fuel cell and the other with a 60 kW fuel cell, enabling a direct comparison of both variants.

- US Hybrid will develop two fuel cell electric trucks powered by an 80 kW hydrogen fuel cell generator. Each truck is estimated to have 20 kg of hydrogen storage to provide up to 150 miles in drayage operations.

- BAE Systems and Kenworth will develop one PHET with a CNG range extender and catenary-connect capability. The proposed technical concept provides a well-balanced blend of all-electric and CNG-based operation to provide a system that can operate in zero emission (all-electric) mode and in a conventional hybrid electric mode using CNG.

- International Rectifier will develop a PHET, and ultra-fast chargers for use in or near the Ports. The vehicle concept will be capable of operating in a zero emission (all-electric) mode in and around the Ports of Los Angeles and Long Beach. Outside that predetermined Zero Emissions Zone, the Class 8 PHET would switch from all-electric to hybrid-electric mode where the vehicle would operate at higher efficiencies to reduce diesel fuel consumption.

In addition, two PHET technologies were recently added to the 2012 ZECT project having replaced two of the four originally awarded technologies. TransPower will develop two CNG PHETs, each with 30-40 miles of all-electric range (AER) and 150-200 miles of total operating range. US Hybrid will also develop three LNG PHETs by converting LNG drayage trucks with their proprietary hybrid electric drive system to provide up to 40 miles in AER mode and 150-200 miles of range.

Between the ZECT and ZECT II projects, SCAQMD has engaged leading EV integrators and truck OEMs to develop a variety of electric drayage trucks, consisting of eleven zero emission trucks – six battery electric and five fuel cell electric trucks – and seven hybrid electric trucks with extended range using CNG, LNG or diesel ICEs. These demonstrations will yield valuable data and understanding of the capability, benefits as well as limitations of advanced electric trucks in real world drayage operations and help to accelerate the introduction of the technologies into the cargo transport sector. Furthermore, leveraging the technologies and expertise gained from the ZECT projects, SCAQMD will seek opportunities to fund a larger-scale demonstration of zero and near-zero emission cargo transport trucks including a recent application to a grant solicitation from CARB for Zero Emission Drayage Truck Projects under the Low Carbon Transportation Greenhouse Gas Reduction Fund Investment. The project, awarded in early 2016,will demonstrate up to 43 zero emission capable drayage trucks involving four major truck OEMs: BYD, Kenworth, Peterbilt, Volvo, in a truly comprehensive statewide demonstration program in partnership with four other major air districts: Bay Area AQMD, San Joaquin Valley APCD, San Diego APCD and Sacramento Metropolitan AQMD. These trucks will provide drayage service at various ports throughout the state.

Figure 6: Drayage Truck Connected to Demonstration Catenary System in Carson

Lastly, SCAQMD has an ongoing project with Siemens Industry Inc. (Siemens) to develop and demonstrate an overhead catenary system (OCS) using their eHighway wayside power technology for heavy-duty trucks. The demonstration involves one mile of catenary power lines in both directions along Alameda Street in the City of Carson with four catenary accessible trucks from Volvo, TransPower and BAE/Kenworth. The trucks will demonstrate a variety of architectures such as diesel hybrid, CNG hybrid and battery electric. The hybrid drive system will extend the operating range of the truck beyond the all-electric range of the catenary system, enabling the truck to perform regional drayage operations and bridge gaps in catenary infrastructure as it is deployed on a regional level. The Siemens' pantograph system will allow for seamless connection and detachment from the catenary power source. 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 lane, the pantograph will automatically retract and the truck will switch to on-board power systems.

The infrastructure portion of the project is in the construction phase with a scheduled completion in the second quarter of 2016. Both trucks–one battery electric and one CNG hybrid–being developed by TransPower were completed in 2015; the Volvo diesel hybrid truck will be completed in mid-2016; and the BAE/Kenworth CNG hybrid truck is scheduled for completion in 2017. In October 2015, one of TransPower's trucks was tested at an off-the-street OCS track in Carson to validate the truck's ability to operate on battery and catenary power.

Develop and Demonstration Ultra Low-Emission Natural Gas Engines for Heavy-Duty Vehicle Applications

Heavy-duty on-road diesel vehicles are currently one of the largest sources of NOx emissions in the South Coast Air Basin. This source category is still projected to be one of the largest contributors to NOx emissions, even as the legacy fleet of older and higher polluting vehicles are retired from operation and replaced by the vehicles meeting the most stringent emission levels required by 2010 emissions standards. NOx reductions in excess of 50% will be needed to meet future federal ambient air quality standards for ozone. The development of ultra-low NOx emission engines would significantly reduce emissions from this source category and assist the region in meeting federal ambient air quality standards. Diesel engines have not achieved the necessary ultra-low emission levels. Natural gas engines, however, have shown promise of achieving significant emission reductions from the current 0.2 g/bhp-hr NOx standard. In addition, since natural engines are currently in mass production, it is likely that commercial scale adoption of ultra low-emission natural engines can be achieved sooner and at lower cost than will be possible with zero emission technologies.

Figure 7: ISL-G Near-Zero Natural Gas Engine

SCAQMD, with funding from the California Energy Commission and the Southern California Gas Company, awarded contracts to three companies to develop engines meeting the CARB Optional NOx Standard of 0.02 g/bhp-hr. The engines cover a range of power and vehicle applications that represent a significant fraction of the on-road heavy duty vehicle population. During 2015, the Cummins Westport 8.9-liter ISL-G NZ (near zero) engine was certified by CARB as meeting the 0.02 g/bhp-hr NOx standard. This engine will begin production in 2016 and will be available to fleets ordering vehicles for delivery later this year as well as those repowering existing vehicles. The technology developed for the ISL engine will be applied in a new project with Cummins Westport to develop and demonstrate the 11.9-liter ISX-G engine to meet the 0.02 g/bhp-hr NOx standard.

Figure 8: Truck with ISL-G-NZ Ultra Low-NOx Engine

Development of a new Cummins 15-liter natural gas engine was carried out in 2015 with results also showing emissions below the 0.02 g/bhp-hr level. Commercialization of this engine,

however, is likely to occur later than the Cummins Westport engines due to higher investment needed for a new engine.

Finally, a team consisting of the Gas Technology Institute, Power Solutions International (PSI) and Ricardo will develop an ultra-low NOx emission engine based on PSI's existing 8.8-liter V8 natural gas engine. This engine is suitable for Class 4-6 trucks currently powered by diesel engines. This project is co-sponsored by SCAQMD and the Southern California Gas Company.

In order to establish market demand for these near zero engines, CARB also adopted optional emission standards of 0.02 g/bhp-hr to enable incentive funding and is modifying incentive programs to increase the funding limits. SCAQMD has issued a program announcement offering funds for these vehicles and expects to provide significant funding as more engine become available.

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.

The following projects contracted during the CY 2015 reporting period illustrate the impact of the SCAQMD's technology deployment and commercialization efforts and include: (a) electric/hybrid vehicle and infrastructure deployment and commercialization efforts in 2015; and (b) hydrogen infrastructure rollout efforts in 2015.

Electric/Hybrid Vehicle and Infrastructure Deployment and Commercialization Efforts in 2015

The continued deployment of near-zero and zero emission electric and hybrid electric vehicles and technologies along with the supporting infrastructure play a key role in moving us ever closer to attaining future air quality standards. Several contracts executed in 2015 bring their own unique contribution to the proliferation of future electric/hybrid technologies and infrastructure.

NREL's Commercial Zero Emission Vehicle (ComZEV) project aims to facilitate the reduction of NOx and GHG emissions through the development of a plan for the commercialization of advanced vehicle technologies in this region. 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 technology options to be evaluated include battery electric vehicles, fuel cell vehicles, catenary/induction electric propulsion systems, and compressed and liquid natural gas internal combustion engines and gas turbines.

The University of California Riverside (UCR) campus serves as a research test bed and demonstration site for plug-in vehicles that can be directly integrated with smart grid technology. A contract was executed with the UCR/College of Engineering-Center for Environmental Research & Technology (CE-CERT) for the evaluation and demonstration of advanced charging technologies and associated vehicle activity to further demonstrate the effectiveness of PEV deployment as part of a smart grid system. PEV utilization will be greatly increased by incorporating advanced charging strategies and/or technologies such as V2G.

Figure 9: UCR's 4 MWs of Photovoltaic Panels Constructed for Sustainable Integrated Grid Initiative

The rapid growth in the number of PEVs purchased and the announcement of longer range (larger battery) PEVs highlights the greater need for residential charging. To help meet the goals set forth in the ZEV Action Plan, further incentives for PEV infrastructure are needed. In response to this need, SCAQMD launched a Residential EV Charging Incentive Pilot Program in December 2015. This program utilizes $500,000 in Clean Fuels funding and $500,000 in Mobile Source Air Pollution Reduction Review Committee (MSRC) funding. Rebates of $250 or $500 for low-income residents are offered to offset the cost of hardware for residential Level 2 chargers. Costs for Level 2 chargers range from $400 to $800 per charger. An online application streamlines the process to apply for the incentives. Chargers will need to be permanently installed and in place for a minimum of three years. Tenants in multi-family dwellings or condominiums can also have chargers installed with the permission of the property owner.

The Rebate Program also includes resources coordinated through local utility agency programs, so that applicants are automatically steered to their local utility EV charger rebate program if a more generous incentive towards hardware and/or installation costs is offered by the local utility. Applicants that are ineligible for their local utility rebate program will be able to apply to the SCAQMD rebate program. Outreach efforts to local residents and to residents of disadvantaged communities are being launched to provide information about the EV charger rebate program through the SCAQMD website, social media, environmental fairs and events, conferences on alternative fuel technologies, and targeted outreach to EV dealers, local governments and councils of government, EV charger manufacturers and OEMs. With current funding, up to 4,000 rebates could be offered, with potentially additional funding being made available to expand the pilot EV charger program.

Figure 10: Residential Level 2 EV Charger

Additional efforts were undertaken in 2015 with several contracts executed out of the Clean Fuels Fund for the installation of electric charging infrastructure and site selection for a DC fast charge network. More information on these various contracts can be found in the Project Summaries section (page 35).

As a separate initiative to accelerate the adoption of PEVs, particularly for residents of disadvantaged communities, SCAQMD started offering the Replace Your Ride Program in July 2015 to help residents purchase newer, less polluting vehicles. This Enhanced Fleet Modernization Program (promoted as the Replace Your Ride Program) was funded with $4.23 million from SCAQMD, MSRC, CARB Greenhouse Gas Reduction Relief Fund (GGRF) and AB 118 Enhanced Fleet Moderation Program, but greatly complements efforts being undertaken

through the Clean Fuels Program. This Program quickly became oversubscribed and has a significant waiting list. In December 2015, the SCAQMD was awarded another $6.4 million in GGRF funding (see Table 5, page 33) to extend the Replace Your Ride Program and make it available to additional residents of disadvantaged communities.

In another effort complementing the Clean Fuels Program, the SCAQMD is upgrading the workplace charging at its Diamond Bar Headquarters to provide more workplace, guest and public charging. SCAQMD currently has 26 Level 2 chargers and one DC fast charger which were installed between 2011 and 2012. However, with well over 60 PEVs owned by SCAQMD employees, as well as the many visitors and members of the public who charge at the facility, the number of available chargers is not sufficient to meet demand. To address this concern SCAQMD initiated plans for the upgrade and expansion of its PEV support infrastructure by the installation of up to 110 level 2 EV chargers at its facility. As the host of multiple alternative fueling stations including Level 2 and DC fast chargers, hydrogen and CNG infrastructure, there is a need to provide additional charging but to also manage the various sources of demand at the facility to avoid demand charges during peak hours in the summer months. The SCAQMD's upgrade, including networking and integration into the building's energy management system, is intended to act as a showcase to promote EV charging and will include development of a set of best practices on installation of workplace charging, policies and integration with demand response, as a guidance document for larger facilities.

Collectively, these PEV and infrastructure projects enable greater penetration of these technologies to the mainstream general public and to residents of disadvantaged communities, going beyond the early adopter stage, and allowing them to experience first-hand how these technologies work. Automakers and EV infrastructure manufacturers, government agencies, and advocacy groups will gain valuable feedback into how to continue to improve and further refine these technologies.

Figure 11: Existing Level 2 Chargers under SCAQMD's Solar Carport

Hydrogen Infrastructure Rollout Efforts in 2015

The SCAQMD has identified the development and deployment of hydrogen infrastructure as one of the agency's top priorities in order to attain federal air quality standards. Hydrogen infrastructure is consistent with the goods movement strategy for zero-emission trucks and infrastructure proposed in SCAG's 2016 Goods Movement Appendix to the Draft 2016-2040 Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS), released December 2015, as well as the joint CARB, SCAQMD and SJVAPCD "Vision for Clean Air: A Framework for Air Quality and Climate Planning". Zero-emission truck deployment is proposed through the year 2040 to meet goals outlined in the Draft 2016-2040 RTP/SCS.

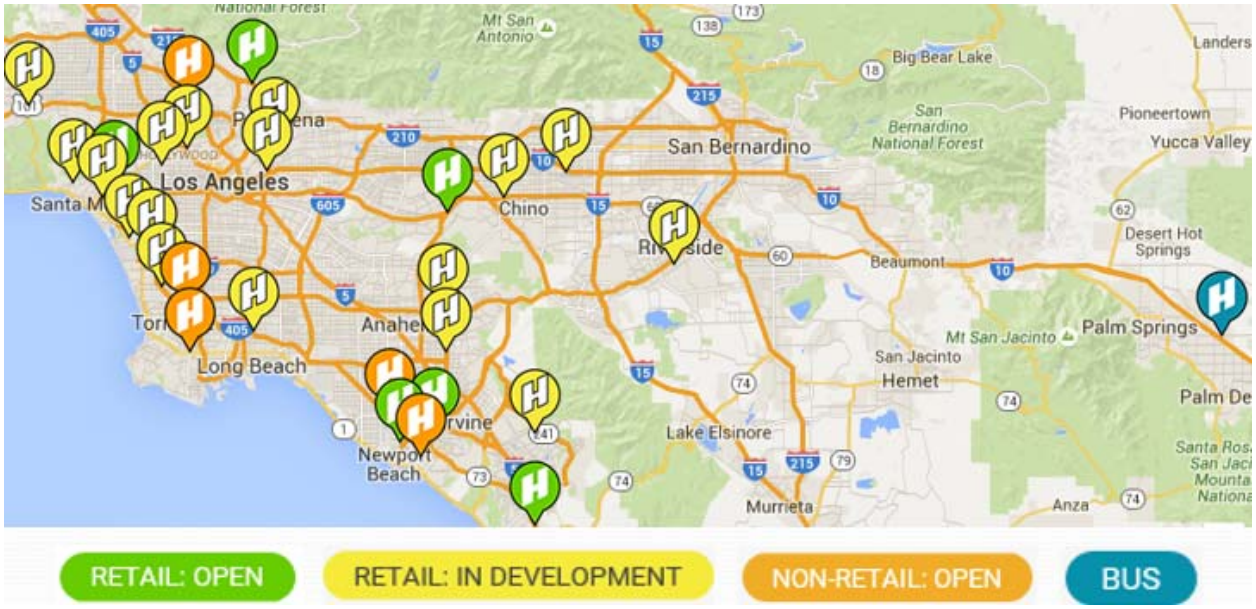


Figure 12: Hydrogen Infrastructure Rollout in the SCAQMD

Source: California Fuel Cell Partnership - http://cafcp.org/stationmap

As part of the planned statewide rollout of new and upgraded hydrogen fueling stations, there are seven open retail stations, five open non retail stations, and 20 stations and a mobile fueler in the process of being constructed and/or upgraded within the South Coast Air Quality Management District in the 2016-2017 timeframe. The newest rollout of hydrogen fueling stations are those that are retail hydrogen stations, typically embedded within an existing gasoline station. Examples of recently opened retail hydrogen stations include the Arco station in La Canada Flintridge and Chevron station in West Los Angeles; retail stations to be opened in 2016-2017 include the Shell station in Torrance, 76 station in Ontario, and Hyundai Chino station. Examples of retail hydrogen stations are shown below.

Figure 13: La Canada Flintridge Retail Hydrogen Station, Located at Arco Gas Station

Figure 14: West Los Angeles Retail Hydrogen Station, Located at Chevron Gas Station

Retail hydrogen stations include point of sale (POS) dispensers capable of conducting retail transactions for the sale of hydrogen on a per kg basis using credit cards, fueling at 350 bar and 700 bar, 35 kg/day in Type A for 70 Mpa fills, and nominal capacity of 100 kg – 200 kg/day. These stations would comply with SAE J2601:2014 and J2719:2011 standards for hydrogen fueling protocol and hydrogen quality. Collectively, the stations would meet Renewable Portfolio Standard (RPS) requirements for providing hydrogen fuel with at least 33% renewable hydrogen. Some of the stations such as the Hyundai Chino station are providing 100% renewable fuel. The renewable hydrogen requirement is fulfilled by solar, energy storage, or renewable energy certificates providing 100% renewable electricity to the station such as for local generation using an electrolyzer or reformer, or by the delivery of 33% or 100% renewable hydrogen produced by a central natural gas reformer, or by a mix of local generation and delivered hydrogen.

Figure 15: Torrance Retail H2 Station, Located at Shell Gas Station

California Department of Food and Agriculture, Division of Weights and Measures (DMS) must pre-certify POS dispensers so that stations can legally sell hydrogen by the kg to refuel fuel cell vehicles. DMS convened a Pre-Rulemaking workshop in August 2013 and further developed test procedures for certifying dispensers to sell hydrogen, while the Governor's Office fast tracked legislation in April 2014. CEC, through its Alternative and Renewable Fuel and Vehicle Technology Program provided $4 million to DMS to develop test standards, equipment, and instrumentation for the commercial sale of hydrogen. This has allowed DMS to carry out field test procedures for hydrogen dispensers as new stations are commissioned. Several other agencies have supported the field testing effort including CARB ($50,000), California Fuel Cell

Partnership ($150,000), CEC ($150,000), and SCAQMD ($100,000). Several stations have already undergone field testing during the station opening process to become designated as open retail or open non-retail stations; these stations include West Sacramento, Diamond Bar, West Los Angeles, University of California Irvine, Coalinga, San Juan Capistrano, San Jose, Costa, Mesa, and Santa Monica (Cloverfield Blvd.). DMS will produce a final report of its field testing effort on hydrogen dispensers in October 2016.

Figure 16: Orange County Sanitation District Non-Retail H2 Station, Located with CNG Station

The intent of the new rollout of retail hydrogen stations is to accelerate the deployment of fuel cell vehicles in the near-term, and for fuel cell trucks and buses in the longer term, once standards for hydrogen fueling protocol and hydrogen quality are worked out between OEMs, station operators, government agencies, and other key stakeholders.

2015 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 6), 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, 2015.

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 January 1 through December 31, 2015, a total of 78 contracts, projects or studies that support clean fuels were executed or amended, as shown in Table 3 (page 30). The major technology areas summarized are (listed in order of funding priority during the CY): engine systems, electric/hybrid technologies and infrastructure, hydrogen and mobile fuel cell technology and infrastructure, outreach and technology transfer, fuels and emission studies, emission control technologies, and fueling infrastructure and deployment. The distribution of funds based on technology area is shown graphically in Figure 17 (page 28). 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 2015 reporting period are shown below with the total projected project costs:

- SCAQMD Clean Fuels Fund Contribution $10,659,033
- Total Cost of Clean Fuels Projects $47,284,929

Each year, the SCAQMD Governing Board approves funds to be transferred to the General Fund Budget for Clean Fuels administration. For 2015, the Board transferred $1 million for workshops, conferences, co-sponsorships and outreach activities as well as postage, supplies and miscellaneous costs for participation in special conferences. Only the funds committed by December 31, 2015, are included within this report. Any portion of the Clean Fuels Funds not spent by the end of Fiscal Year 2015-16 ending June 30, 2016, 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 2015 totaling $2.75 million is listed within Table 4 (page 33).

Appendix B lists the 112 Clean Fuels Fund contracts that were open and active as of January 1, 2016.

For Clean Fuels executed and amended contracts, projects and studies in 2015, the average SCAQMD contribution is approximately 22 percent of the total cost of the projects, identifying that each dollar from the SCAQMD was leveraged with nearly four dollars of outside investment. The typical leverage amount is $3-$4 for every $1 of SCAQMD Clean Fuels funds, but 2015 notably had a couple of significant contracts, significant both in funding and in the impact they hopefully will make in strides toward developing and commercializing clean transportation technologies.

During 2015, the distribution of funds for SCAQMD executed contracts, purchases and contract amendments with additional funding for the Clean Fuels Program totaling approximately $10.7 million are shown in **Figure 17** below.

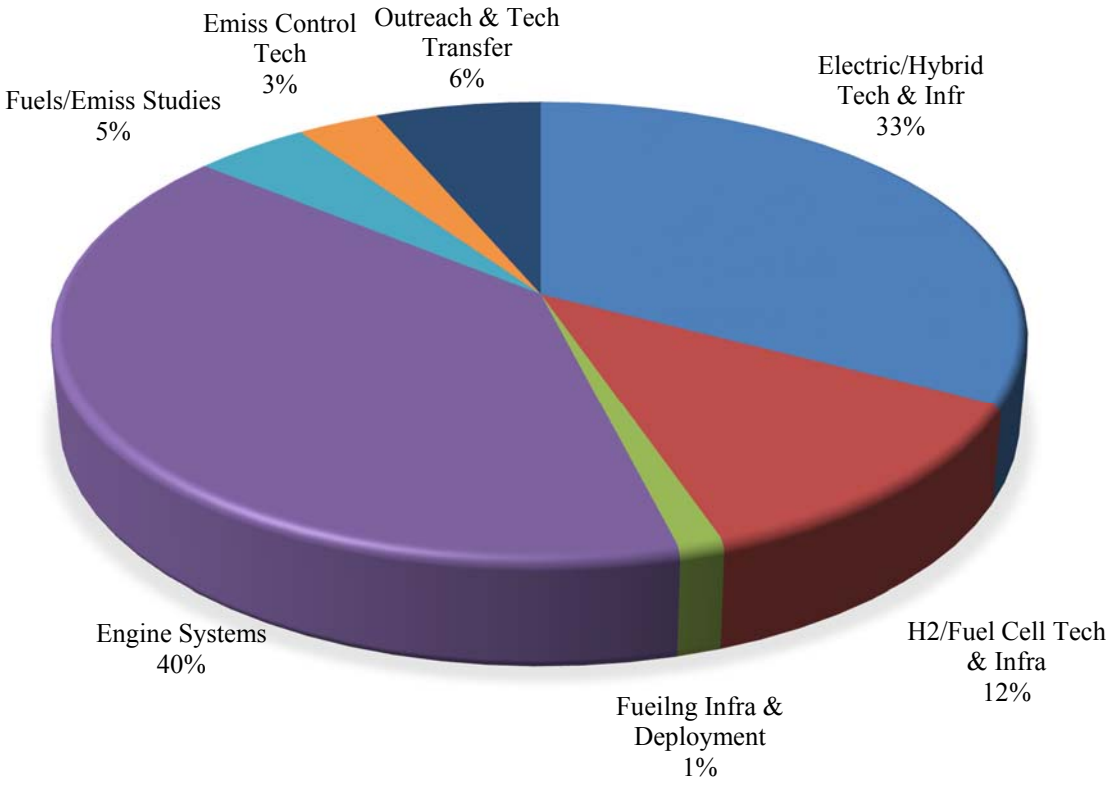


Figure 17: Distribution of Funds for Executed Clean Fuels Projects CY 2015 ($10.7 million)

Table 3 (page 30) provides a breakdown of this $10.7 million in executed contracts. Table 4 (page 33) provides information on outside funding recognized and received into the Clean Fuels Fund ($2.75 million) for contracts executed in CY 2015. Additionally, the SCAQMD continued to seek funding opportunities and Table 5 (page 33) lists the additional $8,560,056 awarded in 2015 for projects that will be implemented as part of the Clean Fuels Program or which align well or will be complementary to the Clean Fuels Program.

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, 2015, the firm of Simpson and

Simpson, CPAs 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. Simpson and Simpson CPAs 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 78 new and continuing contracts, projects and studies that received SCAQMD funding in 2015 are summarized in Table 3, together with the funding authorized by the SCAQMD and by the collaborating project partners.

Table 3: Contracts Executed or Amended (w/$) between January 1 & December 31, 2015

Contract	Contractor	Project Title	Start Term	End Term	SCAQMD $	Project Total $
Electric/Hybrid Technologies and Infrastructure						
10659	Electric Power Research Institute	Data Collection to Further Evaluate Performance and Operational Benefits to Optimize Fleet of Medium-Duty Plug-In Hybrid Vehicles	07/27/10	09/30/16	250,000	844,678
13433	U.S. Hybrid Corporation	Develop and Demonstrate Two Class 8 Zero-Emission Electric Trucks	06/26/13	09/30/17	75,000	150,000
14052	Altec Capital Services, LLC	Lease of Two Plug-In Hybrid Electric Vehicles	01/02/15	01/01/20	61,302	61,302
14336 & 15665	Los Angeles Department of Water & Power & City of Santa Monica	Install and Upgrade EV Charging Infrastructure (Administer SoCalEV Infrastructure Project)	07/31/15	04/03/16	0	1,383,409
15382	ChargePoint, Inc.	Install Electric Charging Infrastructure	01/23/15	01/22/17	162,000	162,000
15448	University of California Los Angeles	Site Selection for DC Fast Charge Network	04/21/15	04/30/16	10,000	10,000
15650	University of California San Diego	Develop and Demonstrate Forecasting for Larger Solar Arrays with Storage and EV Charging	07/17/15	01/16/18	98,908	1,655,278
15680	National Renewable Energy Laboratory	ComZEV – Develop Detailed Technology and Economics-Based Assessment for Heavy-Duty Advanced Technology Development	08/28/15	08/27/16	500,000	500,000
16022	Gas Technology Institute	ZECT II: Develop and Demonstrate One Class 8 CNG Hybrid Electric Drayage Truck	12/04/15	06/30/20	1,578,802	5,627,319
16046	Transportation Power, Inc.	ZECT: Develop and Demonstrate Two Class 8 CNG Plug-In Hybrid Electric Drayage Trucks	12/04/15	09/30/17	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	09/30/17	22,896	1,996,675
Direct Pay	Varies	Establish Residential EV Charging Incentive Pilot Program	09/04/15	09/04/15	500,000	1,000,000
Direct Pay	Clean Fuel Connection, Inc.	EV Charger Installation	03/18/15	03/18/15	5,196	5,196
Direct Pay	ATVLS, Inc.	EV Charger Installation	07/01/15	07/01/15	21,155	21,155
Hydrogen and Mobile Fuel Cell Technologies and Infrastructure						
10046	Air Products and Chemicals, Inc.	Develop and Demonstrate Renewable Hydrogen Energy and Fueling Station	12/21/09	11/01/15	75,000	275,000
13155	Fletcher Jones Motor Cars Inc.	Lease Two F-Cell Mercedes Benz Fuel Cell Vehicles for Two Years	02/08/13	02/08/17	14,598	14,598

Table 3: Contracts Executed or Amended (w/$) between January 1 & December 31, 2015

Contract	Contractor	Project Title	Start Term	End Term	SCAQMD $	Project Total $
Hydrogen and Mobile Fuel Cell Technologies and Infrastructure (cont'd)						
13400	Energy Independence Now	Develop Hydrogen Station Investment Plan and Assess Policies and Incentives for Implementation	04/05/13	12/31/15	80,000	125,000
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	12/31/16	100,000	450,000
15596	US Hybrid	Transfer of Ownership of One Gaseous Hydrogen Electrolyzer, Compressor, Storage Tanks and Associated Hydrogen Equipment	04/15/15	12/31/15	0	0
15599	City of Burbank	Bill of Sale and Transfer of Hydrogen Station Equipment	03/19/15	03/19/15	0	0
15609	ITM Power, Inc.	Installation of Riverside Renewable Hydrogen Fueling Station	10/06/15	10/05/19	200,000	2,934,184
15611	Ontario CNG Station, Inc.	Installation of Ontario Renewable Hydrogen Fueling Station	07/10/15	07/09/20	200,000	2,710,000
15619	H2 Frontier Inc.	Installation of Chino Renewable Hydrogen Station	12/04/15	12/03/20	200,000	4,666,979
15641	Hardin Hyundai	Three-Year Lease of 2015 Tucson Fuel Cell Vehicle	06/15/15	06/14/18	22,862	22,862
15666	Bevilacqua-Knight, Inc.	Participate in CaFCP for CY 2015 and Provide Support for Regional Coordinator	01/01/15	12/31/15	137,800	2,080,808
16039	Lawrence Livermore National Laboratory	Demonstrate Prototype Hydrogen Sensor and Electronics Package	12/10/15	02/09/17	175,000	350,000
16151	Toyota Motor Sales USA	No-Cost Loan of 2015 Toyota Mirai Fuel Cell Vehicle	12/15/15	01/05/16	0	0
16171	Longo Toyota	Three-Year Lease of 2015 Toyota Mirai Fuel Cell Vehicle	12/15/15	12/14/18	24,567	24,567
Direct Pay	Gas Technology Institute	Repair Hydrogen Quality Sampling Adaptor	08/11/15	08/11/15	2,410	2,410
Direct Pay	Toyota Motor Sales USA	Purchase One 2016 Toyota Mirai Fuel Cell Vehicle	12/01/15	12/01/15	56,688	56,688
Engine Systems						
15626	Cummins Westport, Inc.	Develop, Integrate and Demonstrate Ultra Low-Emission Natural Gas Engines for On-Road Heavy-Duty Vehicles	07/10/15	12/31/16	3,500,000	7,233,000
15632	Gas Technology Institute	Develop Ultra Low-Emission Natural Gas Engine for On-Road Medium-Duty Vehicles	09/01/15	06/30/17	750,000	1,800,000
Fueling Infrastructure and Deployment (NG/RNG)						
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

Table 3: Contracts Executed or Amended (w/$) between January 1 & December 31, 2015

Contract	Contractor	Project Title	Start Term	End Term	SCAQMD $	Project Total $
Fuels/Emissions Studies						
15607	University of California Riverside/CE-CERT	Innovative Transportation System Solutions for NOx Reductions in Heavy-Duty Fleets	12/19/15	11/30/16	79,980	139,980
15623	University of California Riverside/CE-CERT	Ozone and SOA Formation from Gasoline and Diesel Compounds	10/02/15	06/30/16	75,000	480,338
15625	University of California Riverside/CE-CERT	Evaluate SOA Formation Potential from Light-Duty GDI Vehicles	10/02/15	06/30/17	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	02/14/17	170,000	270,000
Emission Control Technologies						
15347	West Virginia University Research Corporation	Develop Retrofit Technology for Natural Gas Engines and In-Use Emissions Testing of On-Road Heavy-Duty Trucks	01/09/15	11/08/15	340,000	490,000
Outreach & Technology Transfer						
05128	Mid-Atlantic Research Institute LLC	Technical Assistance for Development, Outreach and Commercialization of Advanced Heavy-Duty and Off-Road Technologies	08/08/05	03/31/17	30,000	30,000
13194	Clean Fuel Connection, Inc.	Technical Assistance with Alternative Fuels, Renewable Energy and EVs, Program Activities for AFVs, Lawn Mower Exchange, Conferences and Outreach	12/07/12	09/30/16	60,000	60,000
13198	Gladstein, Neandross & Associates LLC	Technical Assistance with Alternative Fuels, Emissions Analysis and On-Road Sources	12/14/12	12/31/16	60,000	60,000
14185	Three Squares Inc.	Conduct Education Outreach for the Basin DC Fast Charging Network Project	04/11/14	10/31/16	40,000	40,000
15507	Jerald Cole	Technical Assistance with Alternative Fuels, Emissions Analysis, and Combustion Technologies	01/09/15	01/08/17	30,000	80,000
15516	Cordoba Corporation	Technical Assistance with Construction of Zero Emissions Goods Movement Demonstration Project	03/27/15	03/31/18	74,500	74,500
15610	Goss Engineering, Inc.	Conduct Engineering Services at SCAQMD Headquarters	06/02/15	06/01/16	50,000	50,000
16055	University of California Irvine	Cosponsor Solar Decathlon – Develop and Demonstrate Solar-Powered House at 2015 U.S. DOED Solar Decathlon	11/05/15	02/29/16	50,000	730,000
Direct Pay	Transportation Research Board	Participation for CY 2015 Membership in Transportation Research Board	01/01/15	12/31/15	32,500	256,000

Table 3: Contracts Executed or Amended (w/$) between January 1 & December 31, 2015

Contract	Contractor	Project Title	Start Term	End Term	SCAQMD $	Project Total $
Direct Pay	Various	Cosponsor 24 Conferences, Workshops & Events plus 5 Memberships and 1 Subscription	01/01/15	12/31/15	257,571	5,892,585

Table 4: Supplemental Grants/Revenue Received into the Clean Fuels Fund (31) in CY 2015

Revenue Agreement #	Revenue Source	Project Title	Contractor	SCAQMD Contract #	Award Total $
#14146	Southern California Gas Company	Develop, Integrate and Demonstrate Ultra-Low Emission Natural Gas Engines for On-Road Heavy-Duty	Cummins Westport	15626	500,000
#15022 & #15574	CEC/ AB 118 600-13-008 & PIER 500-12-012	Develop, Integrate and Demonstrate Ultra-Low Emission Natural Gas Engines for On-Road Heavy-Duty Vehicles	Cummins Westport	15626	2,000,000
#15683	Southern California Gas Company	Develop Detailed Technology and Economics Based Assessment for Heavy-Duty Advanced Technology Development	National Renewable Energy Laboratory	15680	250,000
Table 4 lists revenue recognized by SCAQMD into the Clean Fuels Fund (31) only if the pass-through contract was executed during the reporting CY (2015).					**2,750,000**

Table 5: Summary of Federal & State Funding Awarded between Jan. 1 & Dec. 31, 2015

Awarding Entity or Program	Award Date	Purpose	Contractors	Award Total $/Fund
U.S. EPA/ CATI	06/05/15	Develop and Demonstrate Warehouse Rooftop Solar Systems Incorporating Storage and EV Charging; Develop and Demonstrate EV Charging Infrastructure to Support Class 8 Electric Drayage Trucks	University of California San Diego; Transportation Power Inc.	500,000 Fund 17
U.S. EPA/ DERA	08/12/15	On-Road Heavy-Duty Vehicle and Transport Refrigeration Unit Engine Replacement Projects; School Bus Replacement Projects	Multiple Contractors/School Districts	1,160,056 Funds 17 & 80
CARB or BAR	12/29/15	Implementation of the Retire and Replace Component of Enhanced Fleet Modernization Program	Various	1,400,000 Fund 56
CARB or BAR	12/29/15	Implementation of Vehicle Retire and Replace Plus-Up Program	Various	5,000,000 Fund 56
Southern California Gas Company	10/02/15	Develop, Integrate and Demonstrate 11.9L Ultra Low-Emission Natural Gas Engine for On-Road Heavy-Duty Vehicles	Cummins Westport Inc.	500,000 Fund 31
Table 5 provides a comprehensive summary of revenue awarded to SCAQMD during the reporting CY (2015) if it will be considered part of, or complementary to, the Clean Fuels Program, regardless of whether the pass-through contract has been executed.				**8,560,056**

Project Summaries by Core Technologies

The following represents summaries of the contracts, projects and studies executed, or amended with additional dollars, in 2015. They are listed in the order found in Table 3 below by category and contract number. The summaries provide the project title, contractors and subcontractors, SCAQMD cost-share, cosponsors and their respective contributions, contract term and a description of the projects as required by H&SC Section 40448.5.1(d).

Electric/Hybrid Technologies

10659: Data Collection to Further Evaluate Performance and Operational Benefits to Optimize Fleet of Medium-Duty Plug-In Hybrid Vehicles

Contractor: Electric Power Research Institute	SCAQMD Cost-Share	$ 250,000
	Cosponsor	
	Electric Power Research Institute	594,678
Term: 07/27/10 – 09/30/16	Total Cost:	$ 844,678

In 2012 the SCAQMD, in partnership with the DOE, leveraged their previous investments in PHEV development to build a test fleet of PHEV vehicles. The vehicles took advantage of the non-recurring engineering work already invested in the development of Eaton's PHEV drive system. A contract was executed with EPRI to Develop and Demonstrate Fleet of Medium Duty Plug-In Hybrid Electric Vehicles. The vehicles have been delivered to customers and the DOE project ended in June, 2015. Due to delays and additional costs in obtaining CARB and US EPA certification for the vehicles there has not been enough time or funds available to collect, analyze and report on data generated by the vehicles. EPRI has estimated costs to complete the data analysis and reporting requirement of the project to be $844,678 and is requesting SCAQMD to cost share $250,000. The project will collect, analyze and disseminate data from the vehicles for one year.

13433: Develop and Demonstrate Two Class 8 Zero-Emission Electric Trucks

Contractor: US Hybrid Corporation	SCAQMD Cost-Share	$ 75,000
	Cosponsor	
	San Pedro Bay Port's Technology Advancement Program	75,000
Term: 06/26/13 – 09/30/17	Total Cost:	$ 150,000

In October 2012, US Hybrid was awarded $943,810, as part of the ZECT I grant, to develop two battery electric drayage trucks. US Hybrid initially planned to use off-board chargers to support these trucks during demonstration. However, based on input from fleet operators and available EV charging infrastructure at the demonstrator sites, US Hybrid has opted to integrate their electric trucks with an on-board charger to offer simpler charging logistics as well as cost savings for fleet operators. This contract modification is for US Hybrid to develop and integrate a 60 kW on-board charger into each of the two ZECT I demonstration trucks.

14052: Lease of Two Plug-In Hybrid Electric Vehicles

Contractor: Altec Capital Services, LLC	SCAQMD Cost-Share	$ 61,302
Term: 01/02/15 – 01/11/20	Total Cost:	$ 61,302

The Plug-In Hybrid Medium-Duty Truck Demonstration and Evaluation Program was sponsored by the DOE using American Recovery and Reinvestment Act of 2009 funding as well as the SCAQMD. The purpose of the program was to develop a path to migrate plug-in hybrid vehicle technology to medium-duty vehicles by demonstrating and evaluating vehicles in diverse applications. Two of these VIA trucks are being demonstrated at SCAQMD for this project. The VIA design is a series PHEV system. The electric motor provides all the propulsion power directly to the wheels. The gasoline engine provides torque to a generator that provides power to the battery pack and traction motor. The vehicles have up to 47 miles of all-electric range before the engine turns on and provides load-follower torque to the driveshaft while running in charge-sustaining mode. The general assembly process is that VIA purchases completed 2014 trucks from Chevrolet, eliminates the transmissions, and replaces them with generators. A motor and gearbox are attached to the prop-shaft for traction torque, and two inverters are used to control the generator and the motor.

14336 & 15665: Install & Upgrade EV Charging Infrastructure (Administer SoCalEV Infrastructure Project)

Contractor: Los Angeles Department of Water and Power; City of Santa Monica	SCAQMD Cost-Share	$ 0
	Cosponsors	
	CEC	840,750
	SoCalEV Collaborative	542,659
Term: 07/31/15 – 04/30/16	Total Cost:	$ 1,383,409

State, federal and local funds are currently being invested to support battery and plug-in electric vehicles (EVs) and associated charging infrastructure. There was a need to upgrade and expand electric vehicle infrastructure. In 2013, the LADWP asked the SCAQMD to administer the project, which was previously awarded $840,750 by CEC. In 2013, the SCAQMD executed the first five agreements – Memorandum of Agreement (MOA) – with members of the SoCalEV Regional Collaborative to install as well as upgrade existing public EV charging infrastructure at key Southern California locations. In 2014, the SCAQMD executed 12 more agreements, and in 2015 another two agreements. SoCalEV Regional Collaborative members are providing cost-share towards hardware and installation expenses through in-kind labor and/or subcontractors. Data will be collected on charger utilization, charging user patterns, operating costs, electricity used and real-world electric range. By April 2016, 319 Level 2 chargers are expected to be installed at workplaces, destinations, universities, and other key locations.

15382: Install Electric Charging Infrastructure

Contractor: ChargePoint, Inc.	SCAQMD Cost-Share	$ 162,000
Term: 01/23/15 – 01/22/17	Total Cost:	$ 162,000

In order to accelerate the adoption of electric vehicles, SCAQMD executed contracts with the two major manufacturers of Level 2 chargers— ECOtality and ChargePoint, Inc. The intent of these contracts was to install additional public charging infrastructure by incentivizing the cost of hardware and/or installation by providing an incentive of $1,000/charger installed. ECOtality completed installing the majority of its Level 2 charging stations in 2012. The remaining funds in the ECOtality contract were transferred to ChargePoint. ChargePoint has installed approximately 80 Level 2 chargers and is scheduled to complete their work by the end of 2016.

15448: Site Selection for the Basin DC Fast Charging Network

Contractor: University of California Los Angeles Luskin Center	SCAQMD Cost-Share	$ 10,000
Term: 04/21/15 – 04/30/16	Total Cost:	$ 10,000

The UCLA Luskin Center was part of a CEC proposal team to provide site selection services for DC fast charging sites as part of the Basin DC Fast Charging Network. Although 26 sites were originally proposed to CEC, several sites dropped out of the project. As part of site substitution process, the UCLA Luskin Center ran their site selection model to determine the best sites to fulfill multiple criteria including proximity to major freeways or roads, proximity to retail locations, sites with comparable dwell times, and sites which would be predicted to have high charger utilization rates.

15650: Develop and Demonstrate Solar Forecasting for Larger Solar Arrays with Storage and EV Charging

Contractor: University of California San Diego	SCAQMD Cost-Share	$ 98,908
	Cosponsors	
	U.S. EPA	400,000
	CEC	999,984
	California Public Utilities Commission	156,386
Term: 07/17/15 – 01/16/18	Total Cost:	$ 1,655,278

Inherent variability of solar output can impair power quality and grid reliability with wide voltage swings and feeder net load variability in the presence of partial cloud cover that must be matched with fossil generation resources. Plug-in electric vehicles (PEVs) along with other storage technologies can buffer the inherent variability of wind and solar renewable energy sources in the electric system with imaging systems that prepare systems for partial cloud cover. Using sky imaging systems with solar generation can help reduce the amount of storage needed to support variability from solar generation and allow solar generation provide less intermittency on the electrical grid with decreasing reliance on flexible fossil generation resources. Under this project UC San Diego has deployed high accuracy, short-term solar forecasting technologies to allow commercial and industrial ratepayers to maximize their available rooftop space for PV installations, reviewed the potential installation area available on warehouse spaces in the Basin with nearby grid feeder circuits, and reviewed use cases that co-optimize building electrical demand loads with flexible workplace PEV charging and energy storage. A demonstration of the solar forecasting system coupled with solar generation, electrical loads, and charging is being developed.

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

Contractor: National Renewable Energy Laboratory	SCAQMD Cost-Share *(partially received as pass-through funds)*	$ 500,000
Term: 08/28/15 – 08/27/16	Total Cost:	$ 500,000

The objective of the Commercial Zero-Emission Vehicle (ComZEV) project is to facilitate the reduction of NOx and GHG emissions through 2050 through the development of a plan for the commercialization of advanced vehicle technologies in the SCAQMD jurisdictional area. 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 technology options to be evaluated include battery electric vehicles, fuel cell vehicles, catenary/induction electric propulsion systems, and compressed natural gas and liquid natural gas internal combustion engines and gas turbines. The $500,000 funding includes $250,000 from the Southern California Gas Company recognized into the Clean Fuels Fund.

16022: ZECT II: Develop and Demonstrate One Class 8 CNG Hybrid Electric Drayage Truck

Contractor: Gas Technology Institute	SCAQMD Cost-Share	$ 1,578,802
	Cosponsors	
	U.S. DOE *(received as pass-through funds into Fund 61)*	2,813,637
	Gas Technology Institute	311,438
	Other Partners	923,442
Term: 12/04/15 – 06/30/20	Total Cost:	$ 5,627,319

This project is one of the DOE-funded Zero Emission Cargo Transport II demonstration projects to promote and accelerate deployment of zero emission capable cargo transport technologies in the South Coast Air Basin. Under project management by Gas Technology Institute, BAE Systems will work with Kenworth to develop a CNG hybrid electric drayage truck with optional catenary capability for demonstration in real world drayage operations at the Ports of Los Angeles and Long Beach. The proposed technical concept provides a system with a well-balanced blend of all electric and CNG-based hybrid operation that can operate in zero emission (all-electric) mode in sensitive zones, such as disadvantaged communities around the Ports and along major goods movement corridors, and in a conventional hybrid electric mode using a CNG generator to provide an operating range of up to 250 miles and power output comparable to that of conventional Class 8 drayage trucks.

16046: ZECT: Develop and Demonstrate Two Class 8 CNG Plug-In Hybrid Electric Drayage Trucks

Contractor: Transportation Power, Inc.	SCAQMD Cost-Share	$ 195,326
	Cosponsors	
	U.S. DOE *(received as pass-through funds into Fund 61)*	958,120
	CEC	900,000
	Transportation Power, Inc.	50,000
Term: 12/04/15 – 09/30/17	Total Cost:	$ 2,103,446

This project is for one of the two technologies that were added to the first Zero Emission Cargo Transport (ZECT I) project in 2015. Transportation Power (TransPower) will develop two Class 8 CNG plug-in hybrid electric drayage trucks with zero emission operation capability for demonstration in revenue drayage service with fleet operators at the Ports of Los Angeles and Long Beach. Using a CNG generator in a series hybrid drive configuration, these hybrid trucks will be designed to provide comparable power and torque to those of conventional drayage trucks with a targeted range of 200 miles, including 30-40 all-electric miles. The hybrid technology to be used in this project leverages the advanced electric drive system TransPower has developed for their battery electric trucks, which are currently in demonstration with fleet partners in the South Coast Air Basin. TransPower will also utilize commercially available and widely used CNG engines and components to make the hybrid drive technology more cost-competitive and well-positioned for commercialization.

16047: ZECT: Develop and Demonstrate Three Class 8 LNG Plug-In Hybrid Electric Drayage Trucks

Contractor: US Hybrid Corporation	SCAQMD Cost-Share	$ 22,896
	Cosponsors	
	U.S. DOE *(received as pass-through funds into Fund 61)*	925,000
	CEC	450,000
	TTSI	630,000
	US Hybrid Corporation	90,000
Term: 11/06/15 – 09/30/17	Total Cost:	$ 1,996,675

This project is for the other zero emission truck technology that was added to the ZECT I demonstration project in 2015. US Hybrid will convert three Class 8 liquefied natural gas (LNG) drayage trucks into plug-in hybrid electric trucks with zero emission operation capability for demonstration with fleet operators at the Ports of Los Angeles and Long Beach. US Hybrid will leverage a parallel hybrid electric drive system they have developed for refuse trucks to design a hybrid electric drive system well-suited for port drayage truck operations with comparable or higher power output to that of conventional trucks and a targeted range of 200 miles, including 30-40 all-electric miles.

Direct Pay: Establish Residential EV Charging Incentive Pilot Program

Contractor: Varies	SCAQMD Cost-Share	$ 500,000
	Cosponsor	
	MSRC/AB 2766 Discretionary Fund Program	500,000
Term: 09/04/15 – 09/04/15	Total Cost:	$ 1,000,000

SCAQMD launched a Residential EV Charging Incentive Pilot Program in December 2015 utilizing $500,000 from the Clean Fuels Fund and $500,000 in MSRC funding. Rebates of $250 or $500 (low income residents) are being offered to buy down the cost of hardware for residential Level 2 chargers. Costs for Level 2 chargers range from $400 - $800 per charger. Applicants will fill out a one-page online application and provide proof of charger purchase, lease or purchase of a new or used electric vehicle, utility bill, permit or certification of self-installation with an existing 240V outlet, and photo of the installed charger. Chargers will need to be permanently installed and in place for a minimum of three years. Tenants in multi-family dwellings or condominiums can install chargers with the permission of the property owner, manager or HOA.

Direct Pay: EV Charger Installation

Contractor: Clean Fuel Connection, Inc.	SCAQMD Cost-Share	$ 5,196
Term: 03/18/15 – 03/18/15	Total Cost:	$ 5,196

This project provides funds for the demonstration of Level 2 electric vehicle chargers from several manufacturers including ChargePoint, Clipper Creek, LiteOn, AeroVironment, and BTC Power, Inc. Clean Fuel Connection, Inc. purchased and installed Level 2 chargers at various locations. These chargers have been utilized extensively by SCAQMD Board members, staff, and the general public.

Direct Pay: EV Charger Installation

Contractor: ATVLS, Inc.	SCAQMD Cost-Share	$ 21,155
Term: 07/01/15 – 07/01/15	Total Cost:	$ 21,155

This project provides funds for the demonstration of Level 2 chargers from several manufacturers including ChargePoint, Clipper Creek, LiteOn, AeroVironment, and BTC Power, Inc. ATVLS, Inc. purchased and installed two Level 2 chargers at the City of Wildomar City Hall to provide public charging in an underserved location in the Inland Empire. Additional public charging infrastructure in more remote locations assisted in extending charging corridors throughout the region.

Hydrogen and Mobile Fuel Cell Technologies and Infrastructure

10046: Develop and Demonstrate Renewable Hydrogen Energy and Fueling Station

Contractor: Air Products and Chemicals, Inc.	SCAQMD Cost-Share	$ 75,000
	Cosponsor	
	CARB	200,000
Term: 12/21/09 – 11/01/15	Total Cost:	$ 275,000

Air Products and Chemicals, Inc. was selected by CARB under a solicitation to install a new 350/700 bar hydrogen refueling station at Orange County Sanitation District which was supplied by 100% renewable hydrogen and 100% renewable electricity produced utilizing a molten carbonate fuel cell. The SCAQMD joined the project cofunding the fuel cell and station operation. The hydrogen produced was purified using a hydrogen purification system. The molten carbonate fuel cell system and purification system installed at the water treatment facility under a DOE Cooperative Agreement. The hydrogen fueling station was operated by the National Fuel Cell Research Center and the University of California, Irvine and was co-located with an existing, publicly accessible compressed natural gas fueling station. The hydrogen station was designed to dispense 100 kg/day of hydrogen and achieved a single 4.5 kg fill in 3 minutes from the 700 bar dispenser, achieved 3 consecutive 5 kg fills from the 700 bar dispenser in 45 minutes and achieved 3 consecutive 5 kg fills from the 350 bar dispenser in 25 minutes.

13155: Lease Two F-Cell Mercedes Benz Fuel Cell Vehicles for Two Years

Contractor: Fletcher Jones Motor Cars Inc.	SCAQMD Cost-Share	$ 14,598
Term: 02/08/13 – 02/08/17	Total Cost:	$ 14,598

The SCAQMD extended the lease for two Mercedes F-Cell fuel cell vehicles from Fletcher Jones MotorCars which is conveniently located near the UC Irvine hydrogen fueling station. SCAQMD previously demonstrated Mercedes A-class (smaller) F-Cell vehicles from 2005 to 2009. Mercedes produced about 200 F-Cells as part of this pilot program in the US and Europe. This B-Class F-Cell provides 136 hp and a top speed of 106 mph. Range is improved to about 200 miles compared to the previous A-Class version when refueling at a higher pressure of 700 bar. The vehicles are used in our alternative fuel vehicle fleet to demonstrate new clean fuel vehicles to public and private organizations to promote zero- and low-emission technologies. The lease extension is at a reduced rate compared to the original contract amount of $30,397 for 2 years.

13400: Develop Hydrogen Station Investment Plan and Assess Policies and Incentives for Implementation

Contractor: Energy Independence Now	SCAQMD Cost-Share	$ 80,000
	Cosponsors	
	CaFCP *(received as pass-through funds from CEC into Fund 55 in 2014)*	20,000
	Toyota	25,000
Term: 04/05/13 – 12/31/15	Total Cost:	$ 125,000

Energy Independence Now (EIN), in partnership with SCAQMD, embarked on a project to develop a Hydrogen Network Investment Plan (H2NIP) in order to examine market success factors relative to the launch of fuel cell vehicles (FCV) and infrastructure. The project was broken into two phases. Phase I was completed in 2013. Phase II, funded through a contract amendment executed in 2015, developed an assessment of fuel incentives and renewable hydrogen in California that included findings on hydrogen-related environmental credits, key actions needed to further develop California's Low Carbon Fuel Standard (LCFS) and U.S. EPA's Renewable Fuel Standard (RFS) incentives, and highlighted concerns and drivers for the renewable hydrogen market. The final version of the plan, 'Crediting Hydrogen: Fuel Incentives and Renewable Hydrogen Investment in California' was completed in November 2014. EIN provided hydrogen stakeholders with appropriate information to capture a full range of monetary benefits that are currently available through the LCFS program, an assessment of the current and future impacts of the renewable hydrogen requirements, and alternative options to better incentivize renewable hydrogen investments.

14684: Conduct Hydrogen Station Site Evaluations for Site Certification for Commercial Sale of Hydrogen

Contractor: California Department of Food and Agriculture, Division of Measurement Standards	SCAQMD Cost-Share	$ 100,000
	Cosponsor	
	CaFCP	150,000
	CARB	100,000
	CEC	100,000
Term: 12/11/15 – 12/31/16	Total Cost:	$ 450,000

The California Department of Food and Agriculture, Division of Measurement Standards has requested cofunding to conduct site evaluations at ten hydrogen fueling stations leading to certification of the station for the commercial sale of hydrogen. Hydrogen dispensers certified under this program can then be used at multiple locations in California with a simple one day test similar to gasoline station annual evaluation.

15596: Transfer of Ownership of One Gaseous Hydrogen Electrolyzer, Compressor, Storage Tanks and Associated Hydrogen Equipment

Contractor: US Hybrid Corporation	SCAQMD Cost-Share	$ 0
Term: 04/15/15 – 12/31/15	Total Cost:	$ 0

The transfer of hydrogen equipment from the Five Cities Burbank hydrogen station to US Hybrid did not take place since there was an alternate use for the storage tanks as part of the SCAQMD CNG station upgrade.

15599: Bill of Sale and Transfer of Hydrogen Station Equipment

Contractor: City of Burbank	SCAQMD Cost-Share	$ 0
Term: 03/19/15 – 03/19/15	Total Cost:	$ 0

The City of Burbank formally transferred ownership of the Five Cities Burbank hydrogen station equipment to SCAQMD in order to facilitate the transfer of various pieces of hydrogen equipment to US Hybrid. However, it was subsequently determined to use the storage tanks for the SCAQMD CNG station upgrade.

15609: Installation of Riverside Renewable Hydrogen Fueling Station

Contractor: ITM Power, Inc.	SCAQMD Cost-Share	$ 200,000
	Cosponsors	
	CEC	2,125,000
	ITM Power, Inc.	217,125
	Powertech Labs	232,059
	City of Riverside	160,000
Term: 10/06/15 – 10/05/19	Total Cost:	$ 2,934,184

ITM Power, Inc (ITM) is installing a retail hydrogen station at the City of Riverside fleet yard. This hydrogen station will be co-located with a CNG station and a DC fast charging station for CNG and electric vehicles. The Riverside station will be a renewable station that will fulfill Renewable Portfolio Standard (RPS) requirement for CEC-funded stations, with 33% of the hydrogen being produced locally with an electrolyzer supplied with 100% renewable electricity. The remaining 66% of the hydrogen will be delivered. The station will have a nominal capacity of 100 kg/day, with 35 kg/hour in Type A for 70Mpa fills. The Riverside station can be easily expanded and if needed, could become a 100% renewable station at an additional cost. New 350 bar and 700 bar point of sale (POS) dispensers are being upgraded to allow for the sale of hydrogen as retail transactions using credit cards. The station will meet SAE J2601:2014 and J2719:2011 standards for hydrogen fueling protocol and hydrogen quality. The station is scheduled to be completed in 2016.

15611: Installation of Ontario Renewable Hydrogen Fueling Station

Contractor: Ontario CNG Station, Inc.	SCAQMD Cost-Share	$ 200,000
	Cosponsors	
	CEC	2,125,000
	Ontario CNG Station, Inc.	351,000
	Stratos Fuel LLC	34,000
Term: 07/10/15 – 07/09/20	Total Cost:	$ 2,710,000

Ontario CNG Station, Inc. is installing a retail hydrogen station at a gas station in the City of Ontario, next to the Ontario airport. The hydrogen station is co-located with a CNG station and E85 fueling station, and will also host a DC fast charging station later in 2016. The onsite electrolyzer will produce 65 kg/day, with the remaining 35 kg/day provided through 100% renewable delivered hydrogen in order to meet the RPS requirement for CEC-funded stations. The station will have a nominal capacity of 100 kg/day, with 35 kg/hour I Type A for 70Mpa fills. Capacity at this station could be easily increased if needed, could become a 100% renewable station through the use of renewable energy certificates (REC) for electricity and purchase of additional 100% renewable hydrogen. New 350 bar and 700 bar POS dispensers are being

upgraded to allow for the sale of hydrogen as retail transactions using credit cards. The station will meet SAE J2601:2014 and J2719:2011 standards for hydrogen fueling protocol and hydrogen quality. The station is scheduled to be completed in 2016, and is waiting for a major transformer upgrade by Southern California Edison at this site to accommodate demand by the upgraded hydrogen and CNG stations, and the future DC fast charger.

15619: Installation of Chino Renewable Hydrogen Station

Contractor: H2 Frontier Inc.	SCAQMD Cost-Share	$ 200,000
	Cosponsors	
	CEC	3,000,000
	H2 Frontier Inc.	266,925
	Powertech Labs	500,027
	ITM Power, Inc.	700,027
Term: 12/04/15 – 12/03/20	Total Cost:	$ 4,666,979

H2 Frontier Inc. is installing a 100% renewable hydrogen station at the Hyundai Hydrogen Generating Facility in the City of Chino. The Hyundai Chino station will be one of the few 100% renewable stations in the South Coast Air Basin, and will fulfill Renewable Portfolio Standard (RPS) requirement for CEC-funded stations. Electricity will be 100% renewable through the use of RECs and will be locally generated with an on-site electrolyzer. Delivered 100% renewable hydrogen may be used when the electrolyzer is out of service. The station will have a nominal capacity of 100 kg/day, with 35 kg/hour in Type A for 70Mpa fills. The Chino station can be easily expanded. Its close proximity to the Hyundai off-road testing facility will be used for chassis dynamometer testing and increased durability testing routes adjacent to the station. New 350 bar and 700 bar point of sale (POS) dispensers are being upgraded to allow for the sale of hydrogen as retail transactions using credit cards. The station will meet SAE J2601:2014 and J2719:2011 standards for hydrogen fueling protocol and hydrogen quality. The station is scheduled to be completed in the 2016-2017 timeframe.

15641: Three-Year Lease of 2015 Tucson Fuel Cell Vehicle

Contractor: Hardin Hyundai	SCAQMD Cost-Share	$ 22,862
Term: 06/15/15 – 06/14/18	Total Cost:	$ 22,862

SCAQMD has been working with Hyundai America Technical Center Inc. to become a partner in their fuel cell vehicle demonstration program and has participated in on-road testing of their Tucson fuel cell electric vehicle in a program funded by a grant from the U.S. DOE. Hyundai started limited production of the 2015 Tucson fuel cell vehicle for retail lease only through three specially trained dealerships in our region; Hardin Hyundai is the closest dealership which minimizes emissions for service visits. The Hyundai Tucson fuel cell vehicle is a five-passenger SUV that travels 265 miles before refueling with 70 MPa gaseous hydrogen and has EPA estimated fuel economy of 50 mpg. The vehicle is part of SCAQMD's alternative fuel vehicle fleet to demonstrate new clean fuel vehicles to public and private organizations to promote low-emission technologies.

15666: Participate in CaFCP for CY 2015 and Provide Support for Regional Coordinator

Contractor: Bevilacqua-Knight, Inc.	SCAQMD Cost-Share	$ 137,800
	Cosponsors	
	7 automakers; 5 government agencies; 1 fuel cell provider, and 9 associate and 14 affiliate members	1,943,008
Term: 01/01/15 - 12/31/15	Total Cost:	$ 2,080,808

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 Bevilacqua-Knight, Inc. (BKi) for their portion of the CaFCP's administration. In 2015, the SCAQMD Board contributed $87,800 for membership and up to $50,000, along with four cubicles at SCAQMD Headquarters, to provide support for the CaFCP Regional Coordinator.

16039: Demonstrate Prototype Hydrogen Sensor and Electronics Package

Contractor: Lawrence Livermore National Laboratory	SCAQMD Cost-Share	$ 175,000
	Cosponsor	
	U.S. DOE	175,000
Term: 12/10/15 – 02/09/17	Total Cost:	$ 350,000

Lawrence Livermore National Laboratory (LLNL), in conjunction with Los Alamos National Laboratory, has developed a novel, miniature, solid-state electrochemical sensor with the potential to meet requirements for sensitivity, durability, reliability and operational (environment) requirements at a low enough cost for wide-scale deployment. Cofunding from SCAQMD will enable additional testing by LLNL at a hydrogen station within our region.

16151: No-Cost Loan of 2015 Toyota Mirai Fuel Cell Vehicle

Contractor: Toyota Motor Sales USA	SCAQMD Cost-Share	$ 0
Term: 12/15/15 – 01/05/16	Total Cost:	$ 0

One Toyota Mirai fuel cell vehicle was loaned to SCAQMD for a short term for no cost to accommodate elevated interest in this new vehicle.

16171: Three-Year Lease of 2015 Toyota Mirai Fuel Cell Vehicle

Contractor: Longo Toyota	SCAQMD Cost-Share	$ 24,567
Term: 12/15/15 – 12/14/18	Total Cost:	$ 24,567

SCAQMD has worked with Toyota to demonstrate their previous Highlander fuel cell demonstration vehicle through a program with UC Irvine. Toyota started production of the 2016

Mirai fuel cell 4-passenger sedan. The vehicle is available for retail lease through four specially trained dealerships in our region; Longo Toyota is the closest dealership which minimizes emissions for service visits. The Mirai fuel cell vehicle travels 312 miles before refueling with 70 MPa gaseous hydrogen and has EPA estimated fuel economy of 67 mpg. The vehicle will be placed into our alternative fuel vehicle fleet to demonstrate new clean fuel vehicles to public and private organizations to promote low-emission technologies.

Direct Pay: Repair Hydrogen Quality Sampling Adaptor

Contractor: Gas Technology Institute	SCAQMD Cost-Share	$ 2,410
Term: 08/11/15 – 08/11/15	Total Cost:	$ 2,410

NREL loaned the hydrogen quality sampling adapter to SCAQMD to conduct sampling at hydrogen stations in our region to support the development of new test methods under contract 15020 with UC Irvine. Service available only through Gas Technology Institute was needed before the equipment could be returned to NREL.

Direct Pay: Purchase One 2016 Toyota Mirai Fuel Cell Vehicle

Contractor: Toyota Motor Sales USA	SCAQMD Cost-Share	$ 56,688
Term: 12/01/15 – 12/01/15	Total Cost:	$ 56,688

SCAQMD has worked with Toyota to demonstrate their previous Highlander fuel cell demonstration vehicle through a program with UC Irvine. Toyota started production of the 2016 Mirai fuel cell 4-passenger sedan. The vehicle is available for retail purchase or lease through four specially trained dealerships in our region; Longo Toyota is the closest dealership which minimizes emissions for service visits. The Mirai fuel cell vehicle travels 312 miles before refueling with 70 MPa gaseous hydrogen and has EPA estimated fuel economy of 67 mpg. One Mirai was purchased since it is the first fuel cell vehicle available for purchase in California, and since there is an additional $15,000 incentive available for purchase (not lease) of fuel cell vehicles by public fleets serving disadvantaged communities. The vehicle will be placed into our alternative fuel vehicle fleet to demonstrate new clean fuel vehicles to public and private organizations to promote low-emission technologies.

Engine Systems

15626: Develop, Integrate and Demonstrate Ultra Low-Emission Natural Gas Engines for On-Road Heavy-Duty Vehicles

Contractor: Cummins Westport, Inc.	SCAQMD Cost-Share *(partially received as pass-through funds)*	$ 3,500,000
	Cosponsor	
	Cummins Westport, Inc.	3,733,000
Term: 07/10/15 – 12/31/16	Total Cost:	$ 7,233,000

Heavy-duty on-road diesel vehicles are projected to be the top source of NOx emissions in the South Coast Air Basin (SCAB) in 2023 contributing approximately 50 tons per day of NOx. The early development of ultra-low emission engines that emit 90% lower NOx emissions than

current emission standards, would significantly reduce emissions from this on-road source category and assist the region in meeting federal ambient air quality standards in 2023 and later years. Natural gas fueled engines have demonstrated the ability to meet these low emissions standards now while diesel engines have not. This project will apply technology developed for 8.9-liter natural gas engines to 12-liter natural gas engines that are (1) suitable for on-road heavy-heavy duty vehicle applications such as Class 8 trucks and buses; (2) commercially viable; (3) capable of being certified to the CARB Optional NOx standard of 0.02 g/bhp-hr, and 4) capable of NH3 emissions and fuel economy penalties compared to diesel engines as low as possible. The project includes engine and after-treatment system development, integration into vehicles, and field demonstration leading to commercialization in production vehicles by 2018.

15632: Develop Ultra Low-Emission Natural Gas Engine for On-Road Medium-Duty Vehicles

Contractor: Gas Technology Institute	SCAQMD Cost-Share	$ 750,000
	Cosponsors	
	Ricardo	50,000
	PSI	750,000
	Southern California Gas Company	250,000
Term: 09/01/15 – 06/30/17	Total Cost:	$ 1,800,000

Heavy-duty on-road diesel vehicles are projected to be the top source of NOx emissions in the South Coast Air Basin (SCAB) in 2023 contributing approximately 50 tons per day of NOx. Light-heavy and medium-heavy heavy duty diesel on-road buses and trucks are projected to contribute approximately 18 of the 50 tons per day of NOx in the heavy duty diesel category. The development of ultra-low emission engines that emit 90% lower NOx than current standards for these smaller vehicles would significantly reduce their emissions and assist the region in meeting federal ambient air quality standards in the coming years. Natural gas fueled engines have demonstrated the ability to meet these low emissions standards while diesel engines have not. The objective of this project is to develop an 8.8-liter natural gas engine and associated exhaust after-treatment technology that is (1) suitable for on-road light- and medium-heavy duty vehicle applications such as Class 4-6 trucks and buses; (2) commercially viable; (3) capable of being certified to the CARB Optional NOx standard of 0.02 g/bhp-hr, and (4) NH3 emissions and fuel economy penalties as low as possible. The project does not include vehicle integration and demonstration activities.

Fueling Infrastructure & Deployment (NG/RNG)

16076: Deployment of One Heavy-Duty Natural Gas-Powered Paratransit Vehicle

Contractor: Coachella Valley Association of Governments	SCAQMD Cost-Share	$ 140,000
Term: 12/11/15 – 12/11/19	Total Cost:	$ 140,000

In July 2015, the Board approved funding of $140,000 to support the purchase and deployment of one heavy-duty CNG-powered paratransit vehicle for the purpose of providing alternative fuel powered ground transportation in the Coachella Valley region. The vehicle will be deployed for a minimum of three years through the Coachella Valley Association of Governments' (CVAG) Administration Department with the purpose of providing shuttle services to the homeless. The

intended operator of this vehicle is CVAG's approved operator of Roy's Desert Resource Center (DRC) located in North Palm Springs, CA. The vehicle to be deployed is a 32-foot Class E bus with wheelchair lift and two ADA positions and will be built by Creative Bus Sales. The vehicle will be built on a Ford F550 chassis, powered by a 6.8L Ford V-10 gasoline engine that will be converted to dedicated CNG using a CARB-certified system. The vehicle will be equipped with 54 GGE of fuel storage. The project is expected to provide support of CNG vehicle deployment and demonstrate emission reductions in this region.

Fuels/Emissions Studies

15607: Innovative Transportation System Solutions for NOx Reductions in Heavy-Duty Fleets

Contractor: University of California Riverside/CE-CERT	SCAQMD Cost-Share	$ 79,980
	Cosponsor	
	University of California Riverside/CE-CERT	60,000
Term: 12/19/15 – 11/30/16	Total Cost:	$ 139,980

The objective of this project is to develop a new intelligent routing system for heavy-duty trucks, specifically designed to minimize NOx emissions and fuel consumption. This routing system will be built upon CE-CERT's previous research in eco-routing algorithms for light-duty vehicles by incorporating heavy-duty truck energy and emissions data using appropriate models. This application will provide drivers eco-friendly routes with optimal speed to travel based on traffic and road conditions. CE-CERT will field test the application to validate its accuracy and effectiveness including comparison analysis of the estimated NOx emissions with real world NOx emission measurements.

15623: Ozone and SOA Formation from Gasoline and Diesel Compounds

Contractor: University of California Riverside/CE-CERT	SCAQMD Cost-Share	$ 75,000
	Cosponsor	
	University of California Riverside/CE-CERT via CARB 13-302	405,338
Term: 10/02/15 – 06/30/16	Total Cost:	$ 480,338

Low Vapor Pressure (LVP) compounds are often unaccounted for in air models and emission inventories because of their low volatility. However, recent studies indicate that some LVP components of gasoline and diesel are also reactive and may play a significant role in the formation of ozone and PM2.5 including secondary organic aerosol (SOA). Recent observations from the CalNex study observe that the SOA fraction is most strongly correlated with evaporative and tailpipe gasoline vehicle emissions. While SOA formation from some gasoline components have been individually studied under controlled conditions, studies of the atmospheric fate of lower-volatility compounds in gasoline and diesel are somewhat limited. Given changes in fuel formulations, increased knowledge on the impact of reactivity on SOA formation, potential evaporative and tailpipe losses to the atmosphere, and improved experimental photochemical chambers and instrumentation, a new study of whole gasoline and diesel vapor aerosol formation

would provide beneficial insight. Building on the CARB-funded research program for the study of LVP compounds, UCR CE-CERT will evaluate the evaporation characteristics as well as quantify ozone and SOA formation potential from the LVP compounds in gasoline and diesel. This pilot study is a fuel-related expansion of the on-going research with CARB. Whole gasoline and diesel mixtures will be oxidized inside a state-of-the-art large Teflon chamber, leading to the formation of SOA. Measurements of SOA production will be used to evaluate the performance of SOA formation estimation tools. This will lead to more accurate predictions of SOA formation from specific LVP precursors. In addition, UCR CE-CERT will investigate the chemical composition of SOA from gasoline and diesel vapors using mass spectrometry.

15625: Evaluate SOA Formation Potential from Light-Duty GDI Vehicles

Contractor: University of California Riverside/CE-CERT	SCAQMD Cost-Share	$ 149,972
	Cosponsor	
	University of California Riverside/CE-CERT	75,000
Term: 10/02/15 – 06/30/17	Total Cost:	$ 224,972

Gasoline direct injection (GDI) vehicles are known for higher fuel efficiency and power output but the PM emissions profile is not well understood, especially on 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. This project proposes 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. This study covers testing of four (4) GDI vehicles over Unified Cycle using in tank fuel, and another four (4) vehicles using three types of fuels with different ethanol blending (E10 and E20 for three conventional GDIs, and E10 and E85 for one GDI-FFV. The results of this study will provide valuable information on primary and secondary particulate emissions including SOA from in-use GDI vehicles and help to facilitate a discussion on potential mitigation strategies.

15636: Evaluate PEV Utilization through Advanced Charging Strategies in a Smart Grid System

Contractor: University of California Riverside/CE-CERT	SCAQMD Cost-Share	$ 170,000
	Cosponsor	
	University of California Riverside/CE-CERT	100,000
Term: 12/15/15 – 02/14/17	Total Cost:	$ 270,000

As part of SCAQMD's efforts in deploying in-basin renewable distributed electricity generation with energy storage to support electric transportation technologies, UCR CE-CERT was awarded a contract to initiate the "Sustainable Integrated Grid Initiative" project in late 2012. This project has been deployed and is now in operation at the UCR campus. This project serves as a research test bed and demonstration site for Plug-In Vehicles (PEVs) that can be directly integrated with smart grid technology. UCR/CE-CERT continues to expand their programs focused on transportation emissions, their measurement and mitigation. Based on the relevance and potential

to address SCAQMD's priorities to reduce NOx and PM emissions from transportation sources this contract was awarded to UCR/CE-CERT for the evaluation and demonstration of advanced charging technologies and associated vehicle activity to further demonstrate the effectiveness of PEV deployment as part of a smart grid system. PEV utilization will be greatly increased by incorporating advanced charging strategies and/or technologies such as V2G. With Riverside Public Utilities as a cofunding partner this project will incorporate and evaluate Vehicle-to-Grid Strategies; PEV Activity Analysis and Charge; Light Duty Vehicle DC Fast Charging and Heavy Duty PEV Transit Vehicle DC Fast Charging.

Emission Control Technologies

15347: Develop Retrofit Technology for Natural Gas Engines and In-Use Emissions Testing of On-Road Heavy-Duty Trucks

Contractor: West Virginia University Research Corporation	SCAQMD Cost-Share	$ 340,0000
	Cosponsors	
	CARB	100,000
	West Virginia University Research Corporation	50,000
Term: 01/09/15 – 11/08/15	Total Cost:	$ 490,000

In December 2010, the Board awarded a contract to West Virginia University (WVU) to conduct in-use emissions testing, and if needed, to evaluate emission-reduction potential of retrofit technology on existing and new on-road heavy-duty vehicles. While the test results revealed that test vehicles' in-use emissions were lower than the 2010 U.S. EPA in-use or not-to-exceed emissions standards, ammonia emissions from natural gas vehicles were found to be significantly higher than expected due to the nature of spark-ignited engines. The initial evaluations of technologies to reduce emissions from natural gas engines indicate that a selective catalytic reduction (SCR) system is capable of reducing ammonia and further reducing NOx emissions. However, additional work is required to develop, optimize, and enhance the SCR system's performance and durability. In October 2011, the Board amended the December 2010 award and added a new task to assess real-world in-use emissions from a 70,000-pound loaded 2010 U.S. EPA compliant heavy-duty diesel vehicle as the vehicle was driven over a 2,500-mile route between Morgantown WV and Riverside CA. The real-world in-use emissions assessment showed that the combined diesel particulate filter and SCR system achieved low levels of PM and NOx emissions for over 90% of the 2,500-mile trip characterized by mostly sustained freeway operation. The real-world in-use test results necessitate a need to enhance the assessment study to cover urban traffic conditions that are characteristic of heavy-duty vehicle operations in the South Coast Air Basin. In September 2013, the Board awarded a contract to WVU for $340,000 to develop, optimize, and enhance the SCR system to reduce ammonia and NOx emissions from a heavy-duty natural gas engine and conduct real-world in-use emissions testing of heavy-duty vehicles, each loaded to approximately 70,000 pounds, while driven over typical drayage truck routes in the Basin.

Outreach & Technology Transfer

05128: Technical Assistance for Development, Outreach and Commercialization of Advanced Heavy-Duty and Off-Road Technology

Contractor: Mid-Atlantic Research Institute LLC	SCAQMD Cost-Share	$ 30,000
Term: 08/08/15 – 03/31/17	Total Cost:	$ 30,000

In August 2015, Mid-Atlantic Research Institute LLC was tasked under an existing level-of-effort contract to assist WVU (another SCAQMD contractor) to develop, optimize and enhance the SCR system's performance and durability, specifically for addressing ammonia emissions.

13194: Technical Assistance with Alternative Fuels, Renewable Energy and EVs, Program Related Activities for AFVs, Lawn Mower Exchange, Conferences and Outreach

Contractor: Clean Fuel Connection Inc.	SCAQMD Cost-Share	$ 60,000
Term: 12/07/12 – 09/30/16	Total Cost:	$ 60,000

SCAQMD relies on expert input, consultation and support to manage a number of programs conducted under the Clean Fuels Program and incentive programs. Clean Fuel Connection (CFC) is providing technical assistance with alternative fuels, renewable energy and electric vehicles to promote, assess, expedite, and deploy the development and demonstration of advanced, low- and zero-emissions mobile and stationary technologies. This modification to increase available funds under this existing Contract is for administrative support to enable the range of activities involved in implementing the Clean Fuels Program and associated complimentary programs as needed. Support is necessary to enhance or expand existing program-related activities associated with performing or meeting program objectives such as: alternative fuel vehicles (AFVs) demonstration program; lawn mower exchange program; technical conferences; and other outreach activities.

13198: Technical Assistance with Alternative Fuels, Emissions Analysis and On-Road Sources

Contractor: Gladstein, Neandross & Associates LLC	SCAQMD Cost-Share	$ 60,000
Term: 12/14/12 – 12/31/16	Total Cost:	$ 60,000

This contract extension adds $60,000 to continue to leverage 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, emissions analysis and heavy-duty on-road sources.

14185: Conduct Education Outreach for the Basin DC Fast Charging Network Project

Contractor: Three Squares Inc.	SCAQMD Cost-Share	$ 40,000
Term: 04/11/14 – 10/31/16	Total Cost:	$ 40,000

Three Squares Inc. was selected through an RFP process to conduct an education outreach campaign for customers of the Basin DC Fast Charging Network to educate customers 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 electrical vehicle infrastructure; and charging etiquette such as not parking in a space dedicated to electric vehicles when not charging or not staying over posted time limits. Three Squares Inc. has created a SoCalFast website to collect information on charging and make it easily accessible to mainstream consumers and is reaching out to coordinate with local governments, utilities, OEMs, advocacy groups, and event organizers to publicize installations of DC fast chargers as they are installed in the South Coast Air Basin. Three Squares Inc. will organize ribbon cuttings as each DC fast charger comes online, both separately and as part of an overall traditional and social media campaign.

15507: Technical Assistance with Alternative Fuels, Emissions Analysis and Combustion Technologies

Contractor: Jerald Cole	SCAQMD Cost-Share	$ 30,000
	Cosponsor	
	CEC *(received as pass-through funds into Fund 63 in 2013)*	50,000
Term: 01/09/15 – 01/08/17	Total Cost:	$ 80,000

Jerald Cole of Hydrogen Ventures is conducting an evaluation of upgraded hydrogen equipment and meters for the hydrogen stations undergoing upgrades through CEC and SCAQMD cofunding efforts. This evaluation will discuss the relative effectiveness and merits of point-of-sale (POS) dispensers and software; ability of stations to meet SAE J2601:2014 and J2719:2011 standards for hydrogen fueling protocol and hydrogen quality; performance expectations for retail stations such as reliability/up time, back to back fills, and hydrogen purity; and meeting the needs of customers taking delivery of commercially available FCVs. This evaluation will assess all stations undergoing upgrades in the 2015-2018 timeframe.

15516: Technical Assistance with Construction of Zero Emissions Goods Movement Demonstration Program

Contractor: Cordoba Corporation	SCAQMD Cost-Share	$ 74,500
Term: 03/27/15 – 03/31/18	Total Cost:	$ 74,500

Cordoba Corporation has been enlisted to provide technical assistance and consulting services for the Overhead Catenary Truck Demonstration. Siemens, the principle contractor for that project is in need of assistance in the redesign of the infrastructure. Cordoba will provide construction

consulting services and also review, assess and make recommendations on the overall construction portion of the project.

15610: Conduct Engineering Services at SCAQMD Headquarters

Contractor: Goss Engineering, Inc.	SCAQMD Cost-Share	$ 50,000
Term: 06/02/15 – 06/01/16	Total Cost:	$ 50,000

Goss Engineering, Inc. was selected through an informal bid process to provide engineering and construction planning services for the installation of up to 100 Level 2 chargers at SCAQMD headquarters. Technical assistance services included the development of load testing of electric panels, detailed construction plans to obtain a permit for the EV charger installation project with the City of Diamond Bar, evaluation of installation proposals, slope analysis for compliance with ADA accessibility guidelines, short circuit study, and revisions to the construction plans and permit process as required.

16055: Cosponsor Solar Decathlon – Develop and Demonstrate Solar-Powered House at 2015 U.S. DOE Solar Decathlon

Contractor: University of California Irvine	SCAQMD Cost-Share	$ 50,000
	Cosponsors	
	Southern California Edison	150,000
	Five Points Properties	100,000
	The Irvine Company	230,000
	City of Irvine	200,000
Term: 11/05/15 – 02/29/16	Total Cost:	$ 730,000

The biennial U.S. Department of Energy Solar Decathlon competition brings together university teams from across the country with homes they have designed and built that are powered by the sun. The homes must achieve other metrics such as, having low water usage, producing more energy than they consume, power an electric vehicle for specific duty cycles, and maintain comfortable living conditions. The 2015 competition held in October brought together seventeen teams at the Orange County (OC) Great Park with their houses to compete against each other under ten different contests. This co-sponsorship helped TeamOC design and build their competition house entitled Casa Del Sol. TeamOC was a collaboration with students and professors from UC Irvine, Chapman University, Irvine Valley College, and Saddleback College. Over a two year period, students and professors with support from local businesses designed and built their house with inspiration from the California Poppy. The official state flower of California closes its petals during nighttime, cold, or cloudy weather and opens during favorable daylight weather conditions. Some unique energy design features of the home included, horizontally rotating shades, a solar thermal hot water system providing heat for the clothes dryer, use of DC from solar panels to directly charge the electric vehicle along with other DC loads such as cell phones, and a 3-D printing room that created many of the homes lighting fixtures.

Direct Pay: Participation for CY 2015 Membership in Transportation Research Board

Contractor: Transportation Research Board	SCAQMD Cost-Share	$ 32,500
	Cosponsors	
	SCAQMD's Legislative & Public Affairs Office	32,500
	Core Program Participating Members	191,000
Term: 01/01/15 – 12/31/15	Total Cost	$ 256,000

In 2015 the SCAQMD supported the Transportation Research Board (TRB) by participating as a member. The mission of the TRB is to promote innovation and progress in transportation through research. In an objective and interdisciplinary setting, TRB facilitates the sharing of information on transportation practice and policy by researchers and practitioners; stimulates research and offers research management services that promote technical excellence; provides expert advice on transportation policy and programs; and disseminates research results broadly and encourages their implementation. TRB's varied activities annually engage more than 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest by participating on TRB committees, panels and task forces. TRB is one of six major divisions of the National Research Council (NRC) - a private, nonprofit institution that is jointly administered by the National Academy of Sciences, the National Academy of Engineering and the Institute of Medicine - and is the principal operating agency of the National Academies in providing services to the government, the public and the scientific and engineering communities. Sponsors and affiliates provide support for TRB core programs and activities. Sponsors are the major source of financial support for TRB's core technical activities. Federal, state, and local government agencies and professional societies and organizations that represent industry groups are eligible to be TRB sponsors. TRB's annual expenditures for program activities exceed $90 million.

Direct Pay: Cosponsor 24 Conferences, Workshops & Events plus 5 Memberships and 1 Subscription

Contractor: Various	SCAQMD Cost-Share	$ 257,571
	Cosponsors	
	Various	5,635,014
Term: 01/01/15 – 12/31/15	Total Cost	$ 5,892,585

The SCAQMD regularly participates in and hosts or cosponsors conferences, workshops and events. These funds provide support for the 24 conferences, workshops and events sponsored throughout 2015 as follows: Coordinating Research Council's 2015 Real World Emissions Workshop in March; Coordinating Research Council's 2015 Mobile Source Air Toxics Workshop in February; UC Davis's Asilomar 2015 Conference on Transportation & Energy Policy; 2015 Women in Green Forum in August; CTE's International Fuel Cell Bus Workshop in February; UC Irvine's ICEPAG/MGS in March; SCAQMD's Hydrogen Station Grand Opening in March; UC Riverside's PEMS Conference in March; RadTech International's Ultraviolet and Electron Beam West 2015 Conference in March; GNA's Rethink Methane Symposium in June;

CSC Foundation's California Science Fir Awards in May; CleanTechOC's 2015 Symposium; Coordinating Research Council's 2015 Life Cycle Analysis Workshop in October; Adopt-A-Charger's National Drive Electric Week event in September; Burke Rix Communications' Southern California Energy & Water Summit in September; Platia Productions' Santa Monica AltCar Expo in September; Sequoia Foundation's California Asthma Research Conference in October; METRANS Transportation Center's International Urban Freight Conference in October; Clean Fuels Advisory Group participation fees for retreats in January and September; Fuel Cell Seminar & Energy Expo in November; CalETC's LA Auto Show in November; Fuel Cell Seminar booth participation; November Sensor Workshop speaker fees; and finally AWMA's 2016 International Atmospheric Optics Conference to be held in September 2016. Additionally, for 2015 four memberships were renewed for participation in the PEV Collaborative, the Fuel Cell & Hydrogen Energy Association, the Electric Drive Transportation Association, and the Air & Waste Management Association, and four 2016 one membership was renewed toward the end of CY 2015 for the Fuel Cell & Hydrogen Energy Association. One two-year subscription was also renewed for Automotive News.

PROGRESS AND RESULTS IN 2015

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) advancements in engine design, electric power trains, energy storage/conversion devices (e.g., fuel cells and batteries); and 2) implementation of clean fuels (e.g. natural gas, propane and hydrogen) including associated infrastructure. 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 energy systems.

Table 6 provides a list of 47 projects and contracts completed in 2015. 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.

Volvo Plug-In Hybrid Urban Delivery Truck Technology Demonstration

Using hybrid trucks for drayage application (and other local and regional haul applications) can reduce emissions and lowers fuel use significantly. The objective of this project with Volvo Technology of America was to develop, build and demonstrate a prototype Class 8 heavy-duty plug-in hybrid drayage truck with significantly reduced emissions and fuel use. The truck features a 6x2 Mack chassis at 60,000 GCW with the proprietary hybrid driveline, a new energy optimized battery, external charging interface and newly developed energy management and control systems suitable for port drayage application. By utilizing plug-in hybrid technology, fully zero-emission electric mode is possible for limited distances at low speeds, such as in a predetermined zero emission geo-fence. The integration of a plug-in hybrid powertrain with downsized engine (11L in lieu of 13L), along with several improvements to the complete vehicle efficiency are expected to add up to approximately 30% improvement in fuel economy.

The project was completed in July 2015 with a final demonstration of the concept vehicle on a simulated drayage route around Volvo's North American headquarters in Greensboro, NC. The route included all traffic conditions typical of drayage operation in Southern California as well as geo-fences defined to showcase the zero emission capabilities of the truck. The test vehicle successfully completed four consecutive trips with a gross combined weight of 44,000 lb., covering approximately 2 miles out of a total distance of 9 miles per trip in the Zero Emission geo-fence.

This project demonstrates new complete vehicle solutions that can offer significant benefits when applied to a specific duty cycle. This could lead to a change in policymaking for the transportation industry, focusing on reducing real-world emissions impacts of the overall transport solution instead of focusing on individual technologies. Volvo's future work will focus

on improving their analytical tools to better capture engine and exhaust after-treatment component behavior under start-stop or low speed conditions. Volvo believes that this will help identify robust strategies to control the complex plug-in hybrid energy management algorithms in order to maximize the emissions and energy benefits of the vehicle compared to its baseline.

Figure 18: Volvo's PHEV Drayage Truck

Develop, Integrate and Demonstrate Heavy-Duty Natural Gas Engines and Vehicles

On-road natural gas engines are now being used in limited basis as an alternative to diesel engines in transit, refuse and goods movement applications. While the number of these engines has grown, there is still a need to develop natural gas engines in the 11- to 14-liter range to fill the wide array of fleet applications currently served by diesel engines. In 2011, the Board awarded a contract to DOE's National Renewable Energy Laboratory to administer the development, integration and demonstration of heavy-duty natural gas engines and vehicles. The primary objectives of this project included the following:

- Develop a new, high-efficiency, high-performance, high-versatility, low-emissions, heavy-duty 11.9 liter natural gas engine and three-way catalyst after-treatment;
- Certify the new engine at or below EPA/CARB 2010 on-highway emission standards;
- Achieve fuel efficiency within 5-15% of comparable EPA/CARB 2010 on-highway certified diesel engines;
- Commercially launch the resulting "ISX12 G" engine by the end of 2012;
- Achieve OEM availability in a range of vehicles commonly used by fleet operators in the North American regional haul and vocational Class 8 truck and tractor market.

Cummins Westport Inc. (CWI), working as a subcontractor for NREL, successfully completed the project and has developed a heavy-duty, spark-ignited, stoichiometric, cooled exhaust gas recirculation (SI-EGR) natural gas engine certified to EPA/CARB heavy-duty on-highway 2013 emission standards. The SI-EGR engine development is based on the Cummins heavy-duty 11.9 liter diesel engine platform. CWI successfully released the ISX12 G engine to Limited Production manufacturing with ratings up to 350 HP and 1,450 lb-ft beginning in April 2013. This engine is targeted at regional haul tractor and vocational (e.g. refuse collection, concrete

Figure 19: ISX12 G Beta Engine

mixer) truck customers. The ISX12 G engine also meets the U.S. EPA greenhouse gas legislated requirements and EMD+ (Engine Manufacturer's Diagnostics) certification. CWI finalized the product development and validation work for additional engine performance ratings following Limited Production release and began shipping ISX12 G engines with ratings up to 400 HP and 1450 lb-ft in August 2013.

Throughout the ISX12 G engine development program, CWI worked closely with numerous Class 8 truck and tractor OEMs to support their ISX12 G vehicle integration programs. As of the conclusion of this project, the ISX12 G engine is available as a factory-installed option in a number of Class 8 truck & tractor models from many OEMs, including Autocar, Freightliner, Kenworth, Mack, Peterbilt and Volvo.

Figure 20: Trucks Used in Demonstration

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

In December 2010, the Board awarded a contract to West Virginia University (WVU) to conduct in-use emissions testing, and if needed, to evaluate emission-reduction potential of retrofit technology on existing and new on-road heavy-duty vehicles. While the test results revealed that test vehicles' in-use emissions were lower than the 2010 U.S. EPA in-use or not-to-exceed emissions standards, ammonia emissions from natural gas vehicles were found to be significantly higher than expected due to the nature of spark-ignited engines. The initial evaluations of technologies to reduce emissions from natural gas engines indicate that a selective catalytic reduction (SCR) system is capable of reducing ammonia and further reducing NOx emissions. In October 2011, the Board amended the December 2010 award and added a new task to assess real-world in-use emissions from a 70,000-pound loaded 2010 U.S. EPA compliant heavy-duty diesel vehicle as the vehicle was driven over a 2,500-mile route between Morgantown WV and Riverside CA. The real-world in-use emissions assessment showed that the combined diesel particulate filter and SCR system achieved low levels of PM and NOx emissions for over 90% of the 2,500-mile trip characterized by mostly sustained freeway operation. The real-world in-use test results necessitate a need to enhance the assessment study to cover urban traffic conditions that are characteristic of heavy-duty vehicle operations in the South Coast Air Basin. In September 2013, the Board awarded a contract to WVU to develop, optimize, and enhance the SCR system to reduce ammonia and NOx emissions from a heavy-duty natural gas engine and conduct real-world in-use emissions testing of heavy-duty vehicles, each loaded to approximately 70,000 pounds, while driven over typical drayage truck routes in the Basin.

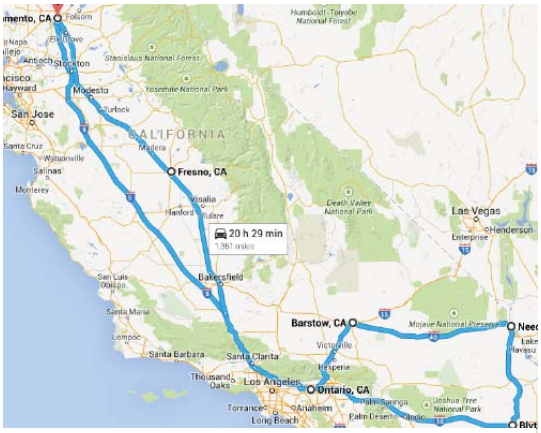


Figure 21: Test Routes for Phase I Study

WVU evaluated real-world emissions from 7 heavy-duty diesel vehicles fueled by diesel and natural gas using a transportable emissions measurement system (TEMS) and a suite of portable emissions measurement system (PEMS)

and investigated multiple pathways of using a passive SCR system for abatement of ammonia and NOx emissions from three-way catalyst (TWC) equipped on-road natural gas engines. The test routes represented real-world driving conditions in the Basin, and the data were segregated into five types of operation, including hill climb, extended highway, regional, local, and near-dock. The test vehicles were operated to and from the ports between Ontario, CA and Ports of LA. The resulting trip were categorized as regional, near-dock and local. Further, additional testing in Irvine, was included as a local urban delivery operation. The study included a MY 2008 Diesel truck to establish baseline emissions for a non-SCR equipped vehicle. Figure 2 shows the distance-specific NOx emissions from the test vehicles over the road measured using the TEMS. The results show that the highway operation resulted in the lowest emissions from all vehicles. Vehicle 7 showed the lowest emissions on highway operating conditions. The near-dock operation characterized by extended idle and creep mode operation resulted in the highest NOx emissions from the diesel vehicles. The average NOx emissions of diesel vehicles using DPF and SCR were 96% lower than a MY 2008 diesel vehicle over the regional cycle. The natural gas truck emissions were 50% lower than DPF-SCR equipped diesel over the regional cycle. The natural gas vehicle showed 88% lower NOx emissions during near-dock port operation compared to the average of all DPF-SCR equipped diesel vehicles.

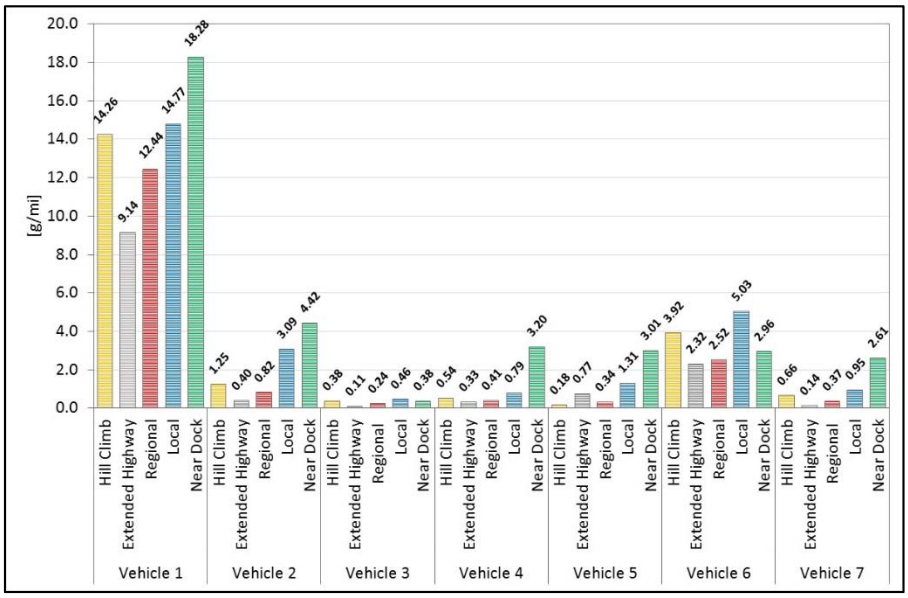


Figure 22: Distance-Specific NOx Emissions from the 7 Test Vehicles

In investigating the SCR system, WVU employed the SCR catalyst as a passive ammonia storage system that can use the NOx slip from TWC as a source to regenerate the stored ammonia while further reducing NOx. NOx slip will be an important issue with aging of TWC in a natural gas engine. An aging catalyst will have lower selectivity to NOx reduction and as a result have increased NOx emissions. Therefore a passive SCR system with TWC as the on-board ammonia storage can effectively lower the NOx profile of CNG through its useful life. For this purpose an old transit bus engine (MY 2009 Cummins ISLG 280) was procured to demonstrate the retrofit technology. The engine was tested in WVU engine laboratory at Morgantown, WV. Three SCR catalysts with varying SCR formulations were fitted downstream of the TWC to absorb the ammonia emissions from TWC as well as reduce NOx slip from the aged TWC. The figure below shows the ammonia and NOx reductions from the three different SCR formulations tested in the study. SCR 2 formulation showed the highest NOx conversion efficiency of 56.9% and the lowest NH3 reduction of 63.6%. While the SCR 3 formulation resulted in the highest NH3 reduction of 82.5% with slight reduction in NOx conversion to 53.9% compared to SCR 2 formulation. As a further extension to this Phase WVU is working with engine controls to change the air-fuel ratio (AFR) of the stoichiometric engine between rich mode (NH3 production mode) and lean mode (NH3 regeneration mode). It is believed that this approach could result in an engine calibration that could run on a leaner air fuel

ratio for enhanced fuel economy. This could potentially increase the operating range of a stoichiometric natural gas engine. The figure below shows the results of the AFR control strategy on the reduction NOx and NH3 emissions from a passive SCR system. The figure shows the increase in ammonia emissions when AFR shifts to rich or close to stoichiometric operation. This mode will be used to load the SCR catalyst with ammonia. Following 80-100% loading of the SCR catalyst, the AFR was shifted to slightly lean mode. This mode drops the ammonia production from the TWC to close to zero, while increasing the TWC out NOx emissions. However, the ammonia stored in the SCR is capable of reducing NOx to near-zero levels. However, the results also show a significant optimization of this strategy is required to develop a strategy that is highly efficient in fuel consumption, lower NOx and ammonia. WVU is conducting an in-depth study, beyond the scope of this project to develop this approach further.

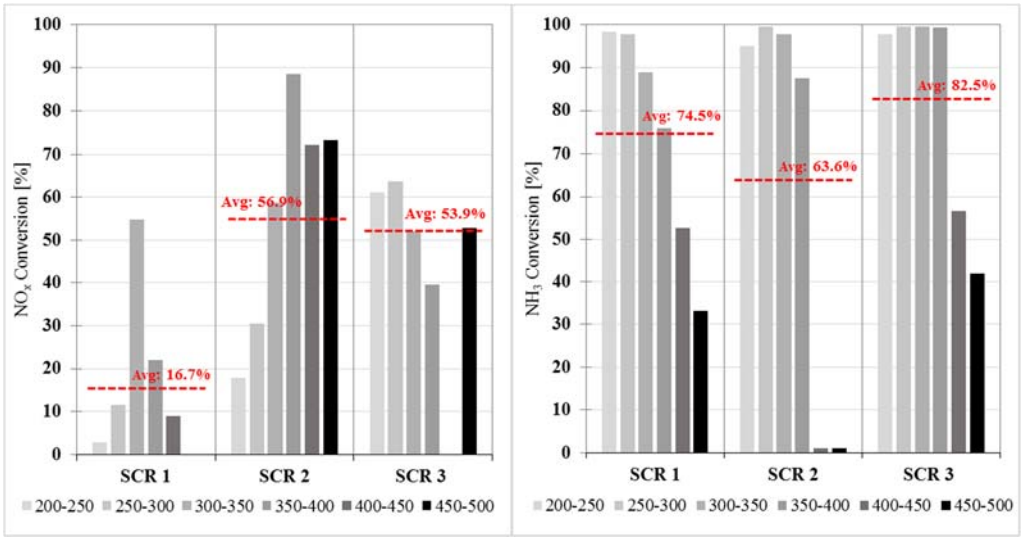


Figure 23: NOx and NH3 reduction efficiency results for varying temperature bins of three different tested zeolite SCR catalysts over an FTP cycle; [SCR 1] Iron (Fe) based low cell density zeolite catalyst, [SCR 2] Iron (Fe) based high cell density zeolite catalyst

Demonstration of Stationary Fuel Cells

In California, a substantial potential exists to capture generator waste heat with an absorption chiller and provide air conditioning to meet a wide spectrum of applications that have significant cooling demands throughout the year. Such combined cooling, heat and power (CCHP) systems offer benefits of increased energy efficiency and reduced emissions of both criteria pollutants and Greenhouse Gases (GHGs). Needed is an ultra-clean, integrated generator/absorption chiller product to enable the California market.

The SCAQMD contracted with UC Irvine which designed and developed a CCHP fuel cell system that was installed at the UC Irvine Medical Center (UCIMC). This system integrates a highly efficient, high-temperature molten carbonate fuel cell with an exhaust-fired absorption chiller, which utilizes the exhaust heat from the fuel cell to generate cooling. The system provides 1.4 MW of reliable, clean electricity and 200 tons of cooling to the medical centers building, while producing virtually zero criteria pollutants. Overall the system is expected to achieve an efficiency approaching 70%. The goal of this project was to provide a "showcase" installation that will inform the California architectural and developer communities of the attributes of fuel cell-based CCHP technology.

The system was installed by UCI's contractor the OHR Company, and was commissioned in December 2015 after completion of the interconnection agreement with Southern California

Edison. The project addressed CCHP technology with the combined benefits of reducing the emissions of GHGs and criteria pollutant emissions associated with electricity generation, distribution and use, enhancing California's economy through technology advancement, employment, and education, reducing the cost-of-electricity, and increasing the reliability and power quality of electricity.

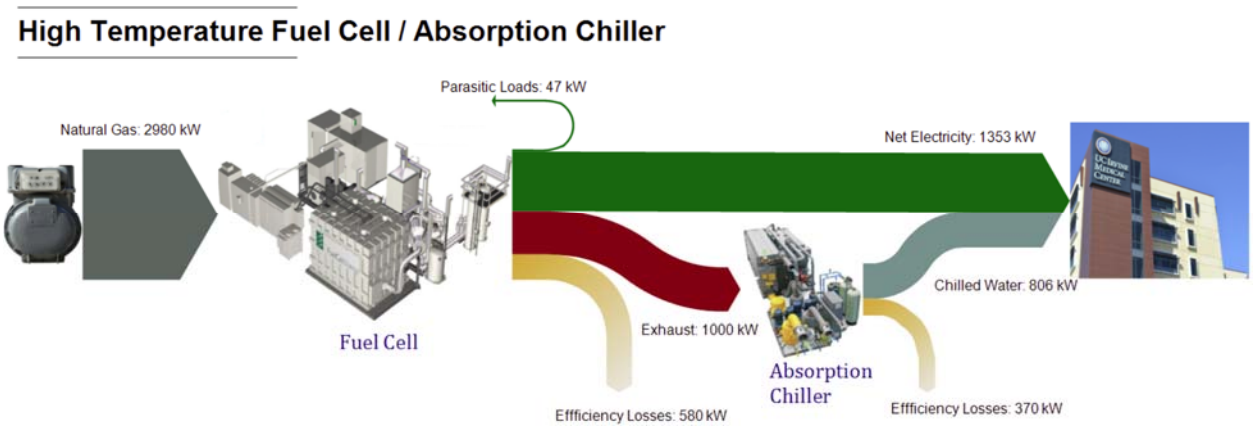


Figure 24: UCI's CCHP System with Absorption Chiller Design

Table 6: Projects Completed between January 1 & December 31, 2015

Contract	Contractor	Project Title	Date
Electric/Hybrid Technologies and Infrastructure			
08219	A123Systems Inc.	Develop and Demonstrate Ten Plug-In Hybrid Electric Vehicles	Jun-2015
11204	AC Propulsion Inc.	Electric Conversion of Medium-Duty Fleet Vehicles	Nov-2015
12862	Volvo Technology of America	Develop Class 8 Drayage Plug-In Hybrid Heavy-Duty Vehicle	Apr-2015
13042	South Bay City Council of Governments	Demonstrate Battery Electric Vehicles	May-2015
13251†	Selman Chevrolet Company	Lease Two 2012 or Newer Chevrolet Volt Extended-Range Electric Vehicles for Three Years	Nov-2015
13418	City of Claremont	SoCalEV Ready EV Charger Installations	Dec-2015
13419	California State University Los Angeles	SoCalEV Ready EV Charger Installations	Dec-2015
13420	University of California Irvine	SoCalEV Ready EV Charger Installations	Dec-2015
13421	County of Los Angeles	SoCalEV Ready EV Charger Installations	Jun-2015
14053†	Electric Power Research Institute	Plug-In Hybrid EV Fleet Participation Agreement	Jul-2015
14074	City of Santa Monica	SoCalEV Ready EV Charger Installations	Jun-2015
14095	City of Covina	SoCalEV Ready EV Charger Installations	Dec-2015
14153	University of California Santa Barbara	SoCalEV Ready EV Charger Installations	Jun-2015
14199	Clean Fuel Connection, Inc.	SoCalEV Ready EV Charger Installations	Dec-2015
14201	California State University San Bernardino	SoCalEV Ready EV Charger Installations	Jun-2015
14207	City of Palmdale	SoCalEV Ready EV Charger Installations	Jun-2015
14208	City of Lake Elsinore	SoCalEV Ready EV Charger Installations	Jun-2015
14209	California State Polytechnic University Pomona	SoCalEV Ready EV Charger Installations	Jun-2015
14210	California State University Long Beach, Office of Research and Sponsored Programs	SoCalEV Ready EV Charger Installations	Jun-2015
14236	California State University Fullerton	SoCalEV Ready EV Charger Installations	Jun-2015

Table 6: Projects Completed between January 1 & December 31, 2015

Contract	Contractor	Project Title	Date
Hydrogen and Mobile Fuel Cell Technologies and Infrastructure			
10046	Air Products and Chemicals, Inc.	Develop and Demonstrate Renewable Hydrogen Energy and Fueling Station	Nov-2015
10061	Hydrogenics Corporation	Maintenance and Data Management for the SCAQMD Hydrogen Fueling Station	Jan-2015
10066†	National Renewable Energy Laboratory	CRADA: Loan a 70 MPa Hydrogen Quality Sampling Apparatus to SCAQMD	Dec-2015
12155†	University of California Irvine	Lease Toyota Fuel Cell Hybrid Vehicle	Dec-2015
13259	Air Products and Chemicals, Inc.	"Five Cities" Program to Demonstrate Hydrogen Fueling Station Operation and Maintenance	Mar-2015
13400	Energy Independence Now	Develop Hydrogen Station Investment Plan and Assess Policies and Incentives for Implementation	Dec-2015
14622	California State University Long Beach, Office of Research and Sponsored Programs	CSULB Student Educational Project to Demonstrate Graphene Fuel Cell Catalysts	May-2015
15020	University of California Irvine	Develop Sampling and Testing Protocols for Analyzing Impurities in Hydrogen	Oct-2015
15419†	SunLine Transit Agency	Disposition of Dispenser from Hydrogenics Station Demonstration at SCAQMD	Dec-2015
15596†	U.S. Hybrid	Transfer of Ownership of One Gaseous Hydrogen Electrolyzer, Compressor, Storage Tanks and Associated Hydrogen Equipment	Dec-2015
15599†	City of Burbank	Bill of Sale and Transfer of Hydrogen Station Equipment	Mar-2015
15666	Bevilacqua-Knight, Inc.	Participate in CaFCP for CY 2015 and Provide Support for Regional Coordinators	Dec-2015
Engine Systems			
13168	National Renewable Energy Laboratory	CRADA: Develop, Integrate and Demonstrate Heavy-Duty Natural Gas Engines and Vehicles	Dec-2015
Fueling Infrastructure and Deployment (NG/RNG)			
07243	City of Commerce	Purchase and Install New Public Access L/CNG Fueling Station	Dec-2015
07309	Post Company Grading	Repower One Off-Road Construction Vehicle	Jun-2015
07312	Mesa Contracting Corporation	Repower 11 Off-Road Construction Vehicles	Jun-2015

Table 6: Projects Completed between January 1 & December 31, 2015

Contract	Contractor	Project Title	Date
Fuels/Emissions Studies			
07236	National Renewable Energy Laboratory	Investigate the Role of Lubricating Oil on PM Emissions from Vehicles	Dec-2015
Stationary Clean Fuel Technologies			
09303	Permacity Solar	Install an Approximate 40kW (AAC) Crystalline Silicon System at SCAQMD Headquarters	Jan-2015
13030	University of California Irvine	Demonstrate a 300 kW Molten Fuel Cell with an Exhaust-Fired Absorption Chiller	Apr-2015
Emission Control Technologies			
15347	West Virginia University Research Corporation	Develop Retrofit Technology for Natural Gas Engines and In-Use Emissions Testing of On-Road Heavy-Duty Trucks	Nov-2015
Outreach and Technology Transfer			
09337†	Mark Weekly, CPA	Follow-Up Assessment of SCAQMD's Compliance with Special Revenue Funds	Jan-2015
11028†	Martin Kay	Technical Assistance on Stationary Source Control Measures and Future Consultation on TAO Activities	Dec-2015
11484	Gladstein, Neandross & Associates LLC	Operate Truck Outreach Centers – Trucking Information Points (FIPS)	Jan-2015
12486†	ICF Resources LLC	Technical Assistance with Goods Movement and Zero-Emission Transportation Technologies	Sep-2015
15505†	Coordinating Research Council, Inc.	Cosponsor 25th Annual CRC Real-World Emissions Workshop	Jun-2015
15506†	Coordinating Research Council, Inc.	Cosponsor the 2015 CRC Mobile Source Air Toxics Workshop	May-215
16029†	Three Squares Inc.	Cosponsor 2015 The Women in Green Forum	Nov-2015

†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
2016 PLAN UPDATE

The Clean Fuels Program (Program) was first created in 1988, along with the SCAQMD's Technology Advancement Office (TAO). Funding for the Program is received through a $1 motor vehicle registration fee. The Clean Fuels Program continually seeks to support the development and deployment of zero and near-zero emission technologies over a broad array of applications and spanning near- and long-term implementation. Planning has been and remains 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 based on the region's ongoing need for emissions reductions and develops a Plan Update for the upcoming calendar year (CY) targeting near-term projects to help achieve those reductions.

Overall Strategy

The overall strategy of the SCAQMD's Clean Fuels Program is based primarily on technology needs identified through the AQMP process and the SCAQMD Board's directives to protect the health of residents in Southern California, which encompasses approximately 16.8 million people (nearly half the population of California). The AQMP is the long-term "blueprint" that defines:

- basin-wide emission reductions needed to achieve federal ambient air quality standards;
- regulatory measures to achieve those reductions;
- timeframes to implement these proposed measures; and
- technologies required to meet these future proposed regulations.

The preliminary 2016 AQMP projects that an approximate 50 percent reduction in NOx is required by 2023 and a 65 percent reduction by 2031, the majority of which must come from mobile sources. These emission reduction needs are further identified in CARB's recent draft discussion document "Mobile Source Strategy" (October 2015). Moreover, the SCAQMD is currently only one of two regions in the nation recognized as an extreme ozone nonattainment area (the other is San Joaquin Valley). Ozone (a key component of smog) is created by a chemical reaction between NOx and VOCs emissions at ground level. This is especially noteworthy because the largest contributor to ozone is NOx emissions, and mobile sources (on- and off-road as well as aircraft and ships) contribute to more than three-fourths of the NOx emissions in this region. Furthermore, NOx and VOC emissions also lead to the formation of PM2.5, particulate matter measuring 2.5 microns in size as contained in a cubic meter of air, expressed as micrograms per cubic meter ($\mu g/m^3$).

The preliminary 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 $\mu g/m^3$) by 2021-2015
- 8-hour Ozone (80 ppb) by 2023 (updated from the 2012 AQMP)
- 1-hour Ozone (120 ppb) by 2022 (updated from the 2012 AQMP)
- 24-hour PM2.5 (35 $\mu g/m^3$) by 2019 (updated from the 2012 AQMP)

The 2016 AQMP will also take an initial look at the emission reductions needed to meet the new federal 8-hour ozone air quality standard of 70 ppb anticipated to be attained by 2037.

The daunting challenge to reduce NOx and PM2.5 require the Clean Fuels Program to encourage and accelerate advancement of transformative fuel and transportation technologies, leading the way for commercialization of progressively lower-emitting fuels and vehicles. The NOx and VOC emission sources of greatest concern to this region are heavy-duty on-road and off-road vehicles. To underscore this concern, the 2013 Vehicle Technologies Market Report[4], released in early 2014 by the Oak Ridge National Laboratory for the Department of Energy, and corroborated by EMFAC 2011 projections, notes that Class 8 trucks comprise 41% of the medium- and heavy-duty truck fleet but consume 78% of the fuel use in this sector. This is especially significant since the report also notes that Class 8 truck sales have continued to increase significantly since 2009. Given the relationship between NOx, ozone and PM2.5, the 2016 Plan Update must emphasize emission reductions in all these areas.

Since the last AQMP, it has become clear that the effect of moving containers through the Ports of Los Angeles and Long Beach and the subsequent movement of goods throughout the region not only have a dramatic impact on air quality but also the quality of life in the communities along the major goods movement corridors. 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, such as electric trucks, plug-in hybrid trucks with all-electric range, zero emission container transport technologies, trucks operating from wayside power including catenary technology and heavy-duty technologies. The findings from the MATES IV[5], 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 ports and goods movement corridor.

For over 20 years, a key strategy of the Clean Fuels Program has been its implementation as a public-private partnership in conjunction 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. However, while the SCAQMD aggressively seeks leverage funds to accomplish more with every dollar, it also strives to act as a leader in technology development and commercialization in an effort to accelerate the reduction of criteria pollutants.

As the state and federal governments have turned a great deal of their attention to climate change, the 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," we have been successful in partnering with the state and federal grants.

Funding Scope

This 2016 Plan Update includes projects to develop, demonstrate and commercialize a variety of technologies, from near-term to long-term, that are intended to provide solutions to the emission control measures identified in the preliminary 2016 AQMP to address the increasing challenges this region is facing to meet air quality standards, including:

[4] http://cta.ornl.gov/vtmarketreport/index.shtml

[5] http://www.aqmd.gov/home/library/air-quality-data-studies/health-studies/mates-iv

1) new and changing federal requirements, such as the recently adopted lower federal 8-hour ozone standard of 70 ppb;
2) implementation of new technology measures; and
3) continued development of economically sound compliance approaches.

The scope of projects in the 2016 Plan Update also needs to remain sufficiently flexible to address new challenges and proposed methodologies that are identified in the preliminary 2016 AQMP, consider dynamically evolving technologies, and incorporate new research and data. The latter, for example, includes the findings from the MATES IV study, which was undertaken to update the emissions inventory of toxic air contaminants, measure the concentration of ultrafine particles and black carbon (an indicator of diesel particulate emissions), and conduct a regional modeling effort to characterize risk to health across the Basin.

Finally, the co-benefits of technologies should also be considered in light of the increasing call for action by the federal government and California's Governor to reduce carbon and greenhouse gases. These actions include President Obama's Climate Action Plan, which notes in the June 2015 progress report that any delays in tackling climate change will come at a huge price (e.g., national security and the economy). But more recently and significantly to this region are Governor Brown's actions including: 1) his Executive Order issued last spring setting a new interim goal to reduce GHGs 40 percent below 1990 levels by 2030, the most ambitious target in North America; 2) his remarks last fall outlining goals to reduce black carbon by 50 percent (and methane and hydrofluorocarbons or HFCs by 40 percent) below current levels by 2030; and 3) his January 2015 state-of-the-state address in which he called for an increase in the amount of electricity generated from renewable sources from 33 to 50 percent as well as reducing the use of petroleum in cars and trucks by up to 50 percent from today's levels. Notably, SB 350 (De León), which the Governor signed last fall, would have codified the Governor's goals outlined in his January 2015 inaugural address, but was amended to remove the 50 percent reduction of petroleum use in cars and trucks. SB 350 still dramatically reshapes California's energy economy, and the Governor has noted his office still has the authority to reduce oil use in vehicles without the bill.

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 provided 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 control measures for the "black box." However, 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, there exists a range of projects that represent near-term to long-term efforts. The SCAQMD Clean Fuels Program tends to support development, demonstration and technology commercialization efforts, or deployment, rather than fundamental research. The general time-to-product for these efforts, from long-term to near-term, is described below.

- Most technology *development* projects are expected to begin during 2016 with durations of about two years. Additional field demonstrations to gain long-term verification of performance, spanning up to two years, 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 2019-2020. 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 2020 or later.

- More mature technologies, those ready to begin field *demonstration* in 2016, are expected to result in a commercial product in the 2017-2018 timeframe. 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.
- *Deployment* or technology commercialization efforts focus on increasing the utilization of clean technologies in conventional applications. It is often difficult to transition users to a non-traditional technology or fuel, 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.

Core Technologies

As previously noted, the SCAQMD Clean Fuels Program maintains flexibility to address dynamically evolving technologies incorporating the latest state-of-the-technology progress. Over the years, the SCAQMD has provided funding for projects for a wide variety of low and zero emission projects. In order to meet the upcoming 2023 8-hour ozone standard, the areas of zero and near-zero emission technologies need to be emphasized. The working definition of "near-zero" is an order of magnitude lower than the existing 0.2 g/bhp-hr NOx or 0.02 g/bhp-hr NOx, close to a combined cycle power plant emissions rate. This effort can be seen in the following sections and in the proposed funding distribution in Figure 25 (page 77). The major core technology areas are identified below with specific project categories discussed in more detail in the following sections. The core technology areas identified reflect the staff's forecast for upcoming projects and needs within the basin but is not intended to be considered a budget.

Not all project categories will be funded due to cost-share constraints, and focus will be on the control measures identified in the 2012 AQMP and potentially the Draft 2016 AQMP, with consideration for availability of suitable projects. The technical areas identified below are clearly 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, staff anticipates there will be upcoming opportunities to leverage state funding through the California Clean Truck, Bus and Off-Road Vehicle and Equipment Technology Program (created by SB 1204, chaptered in September 2014), which designates money from the state's cap-and-trade program for development, demonstration and early commercialization of zero and near-zero emission truck, bus and off-road vehicles, and the Low Carbon Transportation Greenhouse Gas Emission Reduction Fund, which includes funding for zero-emission drayage trucks and truck and bus pilot projects, especially in disadvantaged communities. Finally, 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 an electric drive train with a fuel cell operating on hydrogen fuel or an internal combustion engine operating on natural gas or another alternative fuel as a range extender.

These priorities may shift during the year in keeping with the diverse and flexible "technology portfolio" approach. Changes in priority may occur to: (1) capture opportunities such as cost-sharing by the state government, the federal government, or other entities; or (2) address specific technology issues which affect residents within the SCAQMD's jurisdiction.

The following nine core technology areas are listed by current SCAQMD priorities based on the goals for 2016.

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 leading strategy to achieve these goals is the wide-scale implementation of electric drive systems for all applicable technologies. 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, modest 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.

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 Association (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. In fact, last year, the California Cleaner Freight Coalition, in a report entitled *Moving California Forward: Zero and Low-Emissions Freight Pathways*[6] pointed out that the short distances between freight hubs make electrification a viable option for local freight haul heavy-duty trucks, and in some cases, for on-dock rail which could eliminate some local freight truck trips altogether.

There is a high level of major automobile manufacturers' activity to develop and introduce hybrid-electric technologies in light-, medium- and heavy-duty applications as well as off-road equipment. In particular, there are increasing numbers of diesel- and gasoline-fueled hybrid-electric vehicles and multiple models of light-duty plug-in hybrid and battery electric vehicles (BEVs). Such vehicles offer the benefits of higher fuel economy and range, as well as lower emissions. Hybrid electric technology is not limited to gasoline and diesel engines and can be coupled with natural gas engines (including natural gas engines operating on renewable natural gas), microturbines, and fuel cells for further emission benefits. Additionally, continued advancements in the light-duty arena which, while there is commercially available product, is not yet mainstream technology, may have applications for medium- and heavy-duty vehicles. In fact, the goal of SB 1275 (de León), chaptered in September 2014 establishing the Charge Ahead California Initiative, is to bring one million zero and near-zero emission electric vehicles to California by 2023 as well as to ensure that disproportionally impacted communities benefit from this transition toward cleaner transportation.

[6] http://www.ucsusa.org/sites/default/files/legacy/assets/documents/clean_vehicles/Moving-California-Forward-Executive-Summary.pdf

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;
- demonstration of niche application battery electric vehicles, including school and transit buses 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;
- demonstration of hydraulic hybrid vehicles in heavy-duty cycles with frequent stop-and-go operations, e.g., refuse haulers;
- development of streamlined implementation procedures to prepare and accelerate EV market penetration and commercialization; and
- 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).

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.

In mid-2014 the California Fuel Cell Partnership (CaFCP), with which the SCAQMD works closely as a participating member to further commercialize fuels cells for transportation and installation of the required infrastructure, published the Hydrogen Progress, Priorities and Opportunities (HyPPO)[7]. The HyPPO builds upon CaFCP's 2012 roadmap describing the first network of commercial hydrogen stations in California, which calls for 68 hydrogen fueling stations in cluster communities at specific destinations by 2016. The state's current goal, however, is 100 stations for launching a commercially self-sustaining network to support the growing number of fuel cell vehicles to implement the state's ZEV Action Plan. Over the last three years CEC funding awards using AB 8 dollars, along with financial support from SCAQMD, have made significant inroads to creating the growth path to 100 hydrogen stations. Additional support to encourage renewable hydrogen will be needed. Furthermore, the CaFCP is currently finalizing a medium-/heavy-duty vehicle action plan in coordination with multiple members.

Calendar Years 2015-2017 are a critical timeframe for the introduction of FCVs. In 2015, Toyota commercialized the first FCV available to consumers for purchase, with Hyundai being the first to already offer a FCV for lease in 2014. Honda, along with other OEMS, has also disclosed plans to commercialize FCVs in 2016. 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 Division of Measurement Standards to establish standardized measurements for hydrogen fueling started in 2014, additional efforts to offer hydrogen for sale to general consumers are still needed. In addition, new business models and new sources of funding

[7] http://cafcp.org/sites/default/modules/pubdlcnt/pubdlcnt.php?file=http://cafcp.org/sites/files/Roadmap-Progress-Report2014-FINAL.pdf&nid=2560

besides grants for construction need to be explored 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.

Commencing late 2012, the CEC, which based its AB 118 hydrogen funding strategy on CaFCP's roadmap and the University of California, Irvine's Advanced Power and Energy Program, issued multiple Program Opportunity Notices for hydrogen fuel infrastructure and to date has awarded funding for 51 new hydrogen fueling stations plus operation and maintenance grants for a few of the original older stations. Additionally, the SCAQMD is currently implementing a $6.7 million CEC grant awarded in 2013 to upgrade and refurbish four of the existing hydrogen fueling stations to ensure legacy stations continue operation as FCVs become available in the market. In 2014, the SCAQMD also received an award of $300,000 from CEC to implement a plan for hydrogen readiness in early market communities and that effort is currently underway. The SCAQMD will work closely with state agencies to implement these programs and continue efforts to upgrade and refurbish existing hydrogen infrastructure.

The 2016 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;
- 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; and
- 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.

Engine Systems

Natural gas engines are experiencing huge 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 of 90% lower than the 2010 standards. 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 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; and
- development and demonstration of engine systems that employ advance fuel or alternative fuels, engine design features, improved exhaust or recirculation systems, and aftertreatment devices.

Fueling Infrastructure and Deployment

The importance of natural gas, renewable natural gas 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, along with partial or complete transition to renewable natural gas delivered through the pipeline. 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 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 reduction 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, Emissions and Fuel 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). 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, can contribute to higher NO_x 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 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. One such fuel that the Clean Fuels Program is interested in pursuing is dimethyl ether (DME). This synthetic fuel can be made from renewable natural gas resources and has characteristics similar to gas-to-liquids fuels, i.e., high cetane, zero aromatics and negligible emissions of particulate matter. Volvo has considered commercializing Class 8 trucks using DME, and staff would like to ensure these trucks have lower NOx than the existing standard. A study in the 2015-2016 timeframe on DME is being proposed.

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 emissions studies using biofuels, including DME to evaluate in-use emission composition;
- in-use emissions 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 areas 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.

The use of renewable feedstocks for energy production is a possible option to provide sustainable power for future needs while reducing greenhouse gas emissions and achieving domestic energy diversity. One of the projects that the SCAQMD recently supported in this effort was a bench scale demonstration project using a steam hydrogasification process to produce natural gas from biomass and biosolid (sewage sludge) feedstocks. Steam Hydrogasification Reaction (SHR) has been developed to produce various forms of energy products from carbonaceous resources. SHR is capable of handling wet feedstocks like sludge, does not require expensive oxygen plants and has been demonstrated to be most efficient and cost-effective compared to other conventional gasification technologies. This project successfully demonstrated that the SHR process coupled with a water-gas shift (WGS) reactor can produce gas containing up to 90% methane.

Additionally, alternative energy storage could be achieved through vehicle-to-grid or vehicle-to-building technologies. The University of California Riverside's Sustainable Integrated Grid Initiative, funded in part by the SCAQMD and launched in 2014, 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 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 particulate matter (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 dual fuel engines and advanced aftertreatment technologies for mobile applications (including diesel particulate traps and selective catalytic reduction catalysts); and
- development and demonstration of low-VOC and PM lubricants for diesel and natural gas engines.

Outreach and Technology Transfer

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 25 below presents the potential allocation of available funding, based on SCAQMD projected program costs of $16.4 million for all potential projects. The expected actual project expenditures for 2016 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 2016 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.

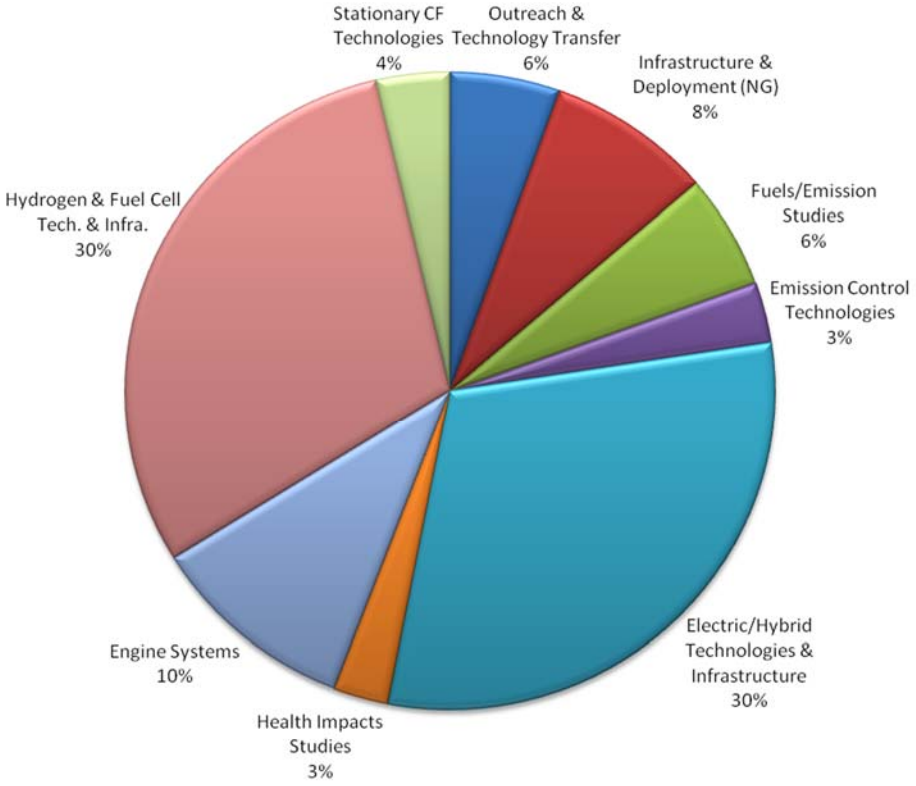


Figure 25: Projected Cost Distribution for Potential SCAQMD Projects in 2016 ($16.4M)

PROGRAM PLAN UPDATE FOR 2016

This section presents the Clean Fuels Program Plan Update for 2016. 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 7 summarizes potential projects for 2016 as well as the distribution of SCAQMD costs in some areas as compared to 2015. The funding allocation continues the focus toward development and demonstration of zero and near-zero emission technologies including the infrastructure for such technologies. For the 2016 Plan, the SCAQMD shifts some emphasis onto electric and hybrid-electric technologies in order to take advantage of funding opportunities afforded by the Greenhouse Gas Reduction Fund Program and the need to continue electrifying goods movement technologies. Focus will continue concurrently on hydrogen and fuel cells given sustained activities by federal and state government and the anticipated roll out of fuel cell vehicles in 2016-2017. A small funding shift to Fueling Infrastructure and Deployment (natural gas and renewable fuels) is also recommended, with modest decreases in other areas given awards over the last year or two. As in prior years, the funding allocations again align well with the SCAQMD's FY 2015-16 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 7 (page 81).

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 7: Summary of Potential Projects for 2016

Proposed Project	Expected SCAQMD Cost $	Expected Total Cost $
Electric/Hybrid Technologies & Infrastructure		
Demonstrate Light-Duty Plug-In Hybrid & Battery Electric Vehicles and Infrastructure	700,000	1,500,000
Develop and Demonstrate Medium- and Heavy-Duty Hybrid Vehicles and Infrastructure	2,000,000	6,000,000
Demonstrate Alternative Energy Storage	300,000	2,000,000
Develop and Demonstrate Electric Container Transport Technologies	2,000,000	6,000,000
Subtotal	$5,000,000	$15,500,000
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 Distributed Hydrogen Production and Fueling Stations	1,500,000	5,000,000
Develop and Demonstrate Medium- and Heavy-Duty Fuel Cell Vehicles	3,000,000	10,000,000
Demonstrate Light-Duty Fuel Cell Vehicles	100,000	100,000
Subtotal	$4,950,000	$19,100,000
Engine Systems		
Develop and Demonstrate Advanced Alternative Fuel Medium- and Heavy-Duty Engines and Vehicles	1,500,000	3,000,000
Develop and Demonstrate Alternative Fuel and Clean Conventional Fueled Light-Duty Vehicles	200,000	1,500,000
Subtotal	$1,700,000	$4,500,000
Fueling Infrastructure and Deployment (NG/RNG)		
Deploy Natural Gas Vehicles in Various Applications	500,000	2,000,000
Develop, Maintain & Expand Natural Gas Infrastructure	350,000	2,000,000
Demonstrate Natural Gas Manufacturing and Distribution Technologies Including Renewables	500,000	7,000,000
Subtotal	$1,350,000	$11,000,000
Fuels/Emission Studies		
Conduct In-Use Emissions Studies for Advanced Technology Vehicle Demonstrations	300,000	800,000
Conduct Emissions Studies on Biofuels and Alternative Fuels	400,000	1,000,000

Table 7: Summary of Potential Projects for 2016 **(cont'd)**

Proposed Project	Expected SCAQMD Cost $	Expected Total Cost $
Fuels/Emission 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	150,000	500,000
Develop and Demonstrate Clean Stationary Technologies	250,000	750,000
Develop and Demonstrate Renewables-Based Energy Generation Alternatives	200,000	1,000,000
Subtotal	$600,000	$2,250,000
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	150,000	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	$450,000	$2,800,000
Outreach and Technology Transfer		
Assess and Support Advanced Technologies and Disseminate Information	500,000	800,000
Support Implementation of Various Clean Fuels Vehicle Incentive Programs	400,000	400,000
Subtotal	$900,000	$1,200,000
TOTALS FOR POTENTIAL PROJECTS	**$16,400,000**	**$66,150,000**

Technical Summaries of Potential Projects

Electric/Hybrid Technologies & Infrastructure

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

Expected SCAQMD Cost: $700,000

Expected Total Cost: $1,500,000

Description of Technology and Application:

All of the major automobile manufacturers are currently developing and commercializing hybrid-electric vehicles, which now come in a variety of fuel economy and performance options. These commercial hybrid EVs integrate a smaller internal combustion engine, battery pack and electric drive motors to improve fuel economy (e.g., Chevy Volt) or performance (e.g., Lexus RX400h).

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 and several automobile manufacturers have announced demonstration or early production plans of "blended" plug-in hybrid electric, extended-range electric vehicles (E-rEV), or highway capable 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. 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. The impact of fast charging on battery life and infrastructure costs is not well understood and will be evolving as three fast DC systems (SAE combo, CHAdeMO and Tesla) compete for international market share.

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.

Recently, automakers have commercialized fuel cell vehicles, with some concepts with plug-in charge capability. Development 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.

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.

This project category is to develop and demonstrate: 1) various PEV architectures; 2) anticipated costs for such architectures; 3) customer interest and preferences for each alternative; 4) prospective commercialization issues and strategies for various alternatives; 5) integration of the technologies into prototype vehicles and fleets; 6) infrastructure (especially in conjunction with

the DOE, CEC and local utilities) to demonstrate the potential clean air benefits of these types of vehicles; 7) support for local government outreach and charging installation permit streamlining; and 8) evaluation of any new promising light-duty vehicle propulsion technologies or fuels.

Potential Air Quality Benefits:

The preliminary 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, customer acceptability of the technology, etc. 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 Medium- and Heavy-Duty Hybrid Vehicles and Infrastructure

Expected SCAQMD Cost: $2,000,000

Expected Total Cost: $6,000,000

Description of Technology and Application:

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. This project category is to investigate 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.

Federal Recovery Act funding combined with state and local support has 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.

Potential Air Quality Benefits:

The preliminary 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 evaluate various hybrid systems and fuel combinations to identify their performance and emissions benefits. Given the variety of hybrid systems under development, it is critical to determine the true emissions and performance of these prototypes, especially if both emissions and fuel economy advantages are achieved.

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, additional technology consisting of nickel sodium chloride, lithium-ion and lithium iron phosphate batteries have shown robust performance. Other technology manufacturers have also developed energy storage devices including 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 further benefits. 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 project will support several projects for development and demonstration of different types of low emission hybrid vehicles using advanced energy 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.

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 preliminary 2016 AQMP. This project is expected 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: $2,000,000

Expected Total Cost: $6,000,000

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 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, magnetic levitation, fuel cell propulsion systems and other wayside power alternatives. This project 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 preliminary 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.

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 limited fuel cell vehicle production announcements by Hyundai, Toyota and Honda for 2014-2015.

In mid-2014 the CaFCP published the *Hydrogen Progress, Priorities and Opportunities* (HyPPO) report, an update of their roadmap describing the first network of commercial hydrogen stations in California.

In 2015, Hyundai and Toyota commercialized fuel cell vehicles, with Honda and other OEMs to initiate delivery in 2016.

Additional work in this project category would develop a plan to secure long-term funding to complete the hydrogen fueling network build-out, provide details how funding can be invested, assess alternative revenue streams such as renewable incentives, propose alternative financing structures to leverage/extend CEC funding, and support 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 preliminary 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, 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 additional funding from other 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 will lead to substantial reductions in NO~~x~~, VOC, CO, PM and toxic air contaminants from vehicles.

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

Expected SCAQMD Cost: $1,500,000

Expected Total Cost: $5,000,000

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 (biomass, digester gas, etc.).

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 50,000 fuel cell vehicles will be deployed by 2017 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 preliminary 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 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: $3,000,000

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 SCAQMD launched demonstrations of Zero Emission Container Transport (ZECT) technologies. In 2015 staff launched ZECT II to develop and demonstrate additional fuel cell truck platforms and vehicles.

This category may include projects in the following applications:

On-Road:
- Transit Buses
- Shuttle Buses
- Medium- & Heavy-Duty Trucks

Off-Road:
- Vehicle Auxiliary Power Units
- Construction Equipment
- Lawn and Garden Equipment
- Cargo Handling Equipment

Potential Air Quality Benefits:

The preliminary 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. 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.

Potential Air Quality Benefits:

The preliminary 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

Proposed Project: Develop and Demonstrate Advanced Alternative Fuel Medium- and Heavy-Duty Engines and Vehicles

Expected SCAQMD Cost: $1,500,000

Expected Total Cost: $3,000,000

Description of Technology and Application:

The objective of this proposed project is to support development and certification of near commercial prototype low-emission heavy-duty alternative fuel engine technologies 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 advance fuel or alternative fuels, engine design features, improved exhaust or recirculation systems, and aftertreatment devices that are optimized using a system approach. This project is expected to result in several projects, including:

- 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 CNG, LNG, LPG, emulsified diesel and GTL 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 200-300 horsepower engines. Higher horsepower alternative fuel engines are beginning to be introduced. However, vehicle range, 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 350 HP or more is limited. Continued development of cleaner dedicated natural gas or other alternative fuel engines such as natural gas-hydrogen blends over 350 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 low-emission alternative fuel 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. Clean alternative fuels, such as natural gas, or natural gas blends with hydrogen 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.

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 compressed air technologies. The potential vehicle projects may include:

- certification of CNG light-duty sedans and pickup trucks used in fleet services;
- resolution of higher concentration ethanol (E-85) affect on vehicle fueling system ("permeation issue");
- certification of E85 vehicles to SULEV standards;
- assessment of "clean diesel" vehicles, including hybrids and their ability to attain SULEV standards; and
- assessment of compressed air technologies.

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

Potential Air Quality Benefits:

The preliminary 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.

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: $350,000

Expected Total Cost: $2,000,000

Description of Technology and Application:

This project supports the development, maintenance and expansion of natural gas fueling station technologies and incorporate advancing concepts to increase the overall number of such fueling stations in strategic locations throughout the Basin including the Ports, 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 begin to age and 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: $500,000

Expected Total Cost: $7,000,000

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 production facilities out-of-state increases the fuel cost anywhere 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 closer, 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. Renewable feed stocks including landfill gas, green waste and waste gases can be processed to yield LNG or CNG.

Industry and government agree that LNG promises to capture a significant share of the heavy-duty vehicle and engine market. LNG is preferred for long distance trucking as it provides twice the energy per unit volume as CNG. This translates to longer driving ranges and lower-weight vehicle fuel storage.

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: $300,000

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 conduct a characterization of application specific drive cycles to best match different transportation technologies to 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: $400,000

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 AB 32, AB 1007 and the Low-Carbon Fuel Standard. It's noteworthy to mention that in 2013 the Low-Carbon Fuel Standard was upheld by the U.S. Court of Appeals for the Ninth Circuit and subsequently in June 2014 opponents were denied further appeal by the Supreme Court. 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, 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.

DME is another fuel which requires evaluation of in-use emissions, especially NOx, in light of Volvo's announcement in 2015 that they will commercialize class 8 trucks using DME in the near future. 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 AB 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 which can be economically 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

The second phase of the project is to validate the technology or strategy on a larger demonstration project over a longer period of time.

An effort to be launched in 2016 will be a first-in-the-nation demonstration of advanced optical remote sensing technologies to better assess and measure emissions from refineries, ships and other sources. These demonstration projects will help measure emissions at lower levels and in near real-time than previously possible, helping enhance future air quality modeling and decision-making. This effort will involve three projects to quantify fugitive emissions from large refineries and other sources of VOCs, such as gas stations, oil wells, marine vessels and rail yards.

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: $150,000

Expected Total Cost: $500,000

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: $200,000

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 and mobile applications. The technologies to be considered include thermal, photovoltaic and other solar energy technologies; wind energy systems; energy storage and conservation 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 substantially 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 preliminary 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: $200,000

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: $150,000

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.

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, initiated in mid-2012, 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.

This project category would include other related studies, 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.

Outreach and Technology Transfer

Proposed Project: Assess and Support Advanced Technologies and Disseminate Information

Expected SCAQMD Cost: $500,000

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: $400,000

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.

Appendix A

SCAQMD Advisory Groups

Technology Advancement Advisory Group

Dr. Matt Miyasato, Chair	SCAQMD
Fabiola P. Lao	Coalition for Clean Air
Dr. Alberto Ayala	California Air Resources Board
Pending	U.S. 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
Pending	Southern California Edison
Philip J. Hodgetts	Clean Air Now
Randall Lewis	Lewis Group of Companies
Tim Olson	California Energy Commission
Pending	Western States Petroleum Association
Cherif Youssef	Southern California Gas Company

SB 98 Clean Fuels Advisory Group

Dr. Matt Miyasato, Chair	SCAQMD
Robert Bienenfeld	American Honda Motor Company Inc
Dr. Blair Folsom	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
Dr. Melanie Marty	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
Dr. Vernon Roan	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
Dr. Nicholas Vanderborgh	Independent Consultant in Fuel Cell Technologies
Michael Walsh	Independent Consultant in Motor Vehicle Pollution Control

Appendix B

Open Clean Fuels Contracts as of January 1, 2016

Contract	Contractor	Project Title	Start Term	End Term	SCAQMD $	Project Total $
Electric/Hybrid Technologies and Infrastructure						
08063	Quantum Fuel Systems Technologies Worldwide, Inc.	Develop & Demonstrate 20 Plug-In Hybrid Electric Vehicles	01/22/08	02/29/16	2,165,613	2,885,266
10659	Electric Power Research Institute	Data Collection to Further Evaluate Performance and Operational Benefits to Optimize Fleet of Medium-Duty Plug-In Hybrid Vehicles	07/27/10	09/30/16	250,000	844,678
11606	Odyne Systems, LLC	Develop and Demonstrate Plug-In Hybrid Electric Drive System for Medium- and Heavy-Duty Vehicles	07/08/11	11/30/16	494,000	2,599,000
11615	Parker Hannifin Corporation	Develop & Demonstrate Up to Four Heavy-Duty Hydraulic Hybrid Vehicles	01/18/13	08/31/16	250,000	2,000,000
12028	Electric Vehicle International, Inc.	Demonstrate and Replace UPS Diesel Delivery Trucks with Zero-Emission Medium-Duty Trucks	09/09/11	09/08/17	1,400,000	4,872,000
13058	Capstone Turbine Corporation	Develop Microturbine Series Hybrid System for Class 7 Heavy-Duty Vehicle Applications	08/12/13	03/30/16	360,000	1,210,000
13396	Transportation Power Inc.	Develop and Demonstrate Seven Class 8 Zero Emission Electric Trucks	04/19/13	12/31/16	375,000	2,285,368
13404	Penske Honda of Ontario	Lease Two Honda Fit Electric Vehicles for Three Years	05/02/13	05/01/16	31,307	31,307
13410	Selman Chevrolet Company	Lease Three 2013 Chevrolet Volt Extended-Range Electric Vehicles for Three Years	04/03/13	04/02/16	41,084	41,084
13426	Transportation Power, Inc.	Develop & Demonstrate Catenary Class 8 Trucks (1 Electric & 1 CNG Platform)	06/07/13	06/06/16	2,617,887	3,182,795
13429	Longo Toyota	Lease One Toyota RAV4 Electric Vehicle for Three Years	04/19/13	04/18/16	19,618	19,618
13433	U.S. Hybrid Corporation	Develop and Demonstrate Two Class 8 Zero-Emission Electric Trucks	06/26/13	09/30/17	75,000	150,000
13439	City of Carson	MOU for Catenary Zero Emission Goods Movement Project	10/01/13	09/30/16	0	0
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
14156	Galpin Motors Inc. (Galpin Ford)	Lease of Two Fusion Energi and One C-Max Energi PHEVs for a Three-Year Period	01/28/14	01/27/17	49,298	49,298
14184	Clean Fuel Connection Inc.	DC Fast Charging Network Provider	04/04/14	06/30/20	250,000	1,318,000
14052	Altec Capital Services, LLC	Lease of Two Plug-In Hybrid Electric Vehicles	01/02/15	01/01/20	61,302	61,302
14202	Adopt-A-Charger	SoCalEV Infrastructure MOA to Install & Upgrade EV Charging Infrastructure	04/14/14	04/30/16	0	0
14204	Associated of Los Angeles	SoCalEV Infrastructure MOA to Install & Upgrade EV Charging Infrastructure	10/10/14	04/30/16	0	0

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	04/23/16	389,000	2,226,571
14224	Complete Coach Works	Develop and Test Retrofit All Electric Transit Bus	04/24/14	02/28/17	395,000	867,182
14256	National Strategies LLC	Develop and Demonstrate Vehicle-2-Grid Technology	09/05/14	03/04/18	250,000	3,377,689
14323	Selman Chevrolet Company	Lease Two 2014 Chevrolet Volt Extended-Range Electric Vehicles for Three Years	03/28/14	03/27/17	30,932	30,932
14336	Los Angeles Department of Water & Power	Install and Upgrade EV Charging Infrastructure (Administer SoCalEV Infrastructure Project)	07/31/15	04/03/16	0	0
15021	Transportation Power Inc.	Upgrade and Demonstrate Two Electric Yard Tractors	07/14/14	12/31/16	75,000	405,000
15382	ChargePoint, Inc.	Install Electric Charging Infrastructure	01/23/15	01/22/17	162,000	162,000
15448	University of California Los Angeles	Site Selection for DC Fast Charge Network	04/21/15	04/30/16	10,000	10,000
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
15665	City of Santa Monica	Install and Upgrade EV Charging Infrastructure (Administer SoCalEV Infrastructure Project)	07/31/15	04/03/16	0	0
15680	National Renewable Energy Laboratory	ComZEV – Develop Detailed Technology and Economics-Based Assessment for Heavy-Duty Advanced Technology Development	08/28/15	08/27/16	500,000	500,000
16022	Gas Technology Institute	ZECT II: Develop and Demonstrate One Class 8 CNG Hybrid Electric Drayage Truck	12/04/15	06/30/20	1,578,802	5,627,319
16046	Transportation Power, Inc.	ZECT: Develop and Demonstrate Two Class 8 CNG Plug-In Hybrid Electric Drayage Trucks	12/04/15	09/30/17	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	09/30/17	22,896	1,996,675
Hydrogen and Mobile Fuel Cell Technologies and Infrastructure						
11150	Hydrogen Frontier, Inc.	Maintenance & Operation of City of Burbank Hydrogen Fueling Station	11/24/10	01/23/16	475,000	1,635,000
10482	California State University Los Angeles	Install and Demonstrate PEM Electrolyzer, Providing Hydrogen Fueling for Vehicles and Utilizing the Technology in the Engineering Technology Curriculum at the University	03/04/11	10/03/17	250,000	1,662,000
11555	University of California Los Angeles	Construct Hydrogen Fueling Infrastructure	12/07/12	12/31/19	400,000	2,589,990

Contract	Contractor	Project Title	Start Term	End Term	SCAQMD $	Project Total $
Hydrogen and Mobile Fuel Cell Technologies and Infrastructure (cont'd)						
12075	Linde, LLC	Expand Hydrogen Fueling Infrastructure	11/02/12	11/02/18	250,000	2,732,177
13155	Fletcher Jones Motor Cars (Mercedes-Benz)	Lease Two F-Cell Fuel Cell Vehicles for Two Years	02/08/13	02/08/17	44,995	44,995
14139	Hyundai America Technical Center Inc.	No-Cost Lease of Fuel Cell Vehicle for Two Years	12/13/13	12/31/17	0	0
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	12/31/16	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	09/14/17	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
15619	H2 Frontier Inc.	Installation of Chino Renewable Hydrogen Station	12/04/15	12/03/20	200,000	4,558,274
15641	Hardin Hyundai	Three-Year Lease of 2015 Tucson Fuel Cell Vehicle	06/15/15	06/14/18	22,862	22,862
16039	Lawrence Livermore National Laboratory	Demonstrate Prototype Hydrogen Sensor and Electronics Package	12/10/15	02/09/17	175,000	350,000
16151	Toyota Motor Sales USA	No-Cost Loan of 2015 Toyota Mirai Fuel Cell Vehicle	12/15/15	01/05/16	0	0
16171	Longo Toyota	Three-Year Lease of 2015 Toyota Mirai Fuel Cell Vehicle	12/15/15	12/14/18	24,567	24,567
Engine Systems						
14364	Cummins Inc.	Develop, Integrate and Demonstrate Ultra-Low Emission Natural Gas Engines for On-Road Heavy-Duty Vehicles	07/14/14	08/20/16	2,061,000	3,869,000
15626	Cummins Westport, Inc.	Develop, Integrate and Demonstrate Ultra Low-Emission Natural Gas Engines for On-Road Heavy-Duty Vehicles	07/10/15	12/31/16	3,500,000	7,233,000
15632	Gas Technology Institute	Develop Ultra Low-Emission Natural Gas Engine for On-Road Medium-Duty Vehicles	09/01/15	06/30/17	750,000	1,800,0000
Infrastructure and Deployment						
05250	Downs Commercial Fueling, Inc.	Purchase & Install New L/CNG Fueling System at Commercial Fueling Station in Temecula	11/04/05	04/30/16	203,137	833,333

Contract	Contractor	Project Title	Start Term	End Term	SCAQMD $	Project Total $
Infrastructure and Deployment (cont'd)						
06042	University of California Los Angeles	Upgrade Existing CNG Public Access Station with Dispenser & Card Reader	09/05/06	12/31/16	15,921	31,842
06084	Clean Energy	Upgrade Existing LNG Facility to L/CNG at Riverside County Waste Management Dept's Aqua Mansa Facility in Riverside	04/13/06	02/28/16	120,000	400,000
06091	City of Whittier	Purchase & Install New Public Access CNG Fueling Station at City Yard	03/18/06	12/31/16	150,000	450,000
07153	Foothill Transit	Purchase & Install New Public Access CNG Refueling Station in Irwindale	11/02/09	06/30/16	250,000	3,350,000
07246	USA Waste of California, Inc., dba L.A. Metro	Purchase & Install New LNG Storage Tank at Long Beach LNG Refueling Station	12/24/08	06/30/17	200,000	440,000
07320	Orange County Transportation Authority	Install New CNG Station in the City of Santa Ana	12/21/07	03/31/16	350,000	5,841,729
08043	University of California Los Angeles	Public Access CNG Refueling Station Upgrade for UCLA Transportation	05/02/08	12/31/16	140,000	350,000
08044	Beaumont Unified School District	Install Limited Access CNG Refueling Station	03/05/09	12/31/16	288,000	615,994
08098	Redlands Unified School District	Purchase & Install New CNG Refueling Station	01/25/08	12/31/17	525,000	700,000
09165	California Cartage Company	Deployment of 2010 Emissions Standards Compliant LNG Trucks	10/31/08	07/31/16	358,000	11,880,000
09218	Rim of the World Unified School District	Install Mountain Safety Equipment on Five New CNG School Buses	01/05/10	12/31/16	65,850	65,850
09364	Rim of the World Unified School District	Construct & Install a CNG Fueling Station	12/30/10	12/31/16	257,000	425,000
10067	Rim of the World Unified School District	Install Mountain Safety Equipment on Seven New CNG School Buses	12/21/09	12/31/16	92,190	92,190
11548	Clean Energy (novated from Mansfield Gas Equipment Systems)	Buydown Incentive Program for CNG Home Refueling Appliance "Phill"	09/07/12	01/31/16	60,000	356,000
12135	Placentia-Yorba Linda Unified School District	Upgrade CNG Fueling Station	11/18/11	11/30/17	60,000	60,000
12267	West Covina Unified School District	Upgrade CNG Fueling Facility	10/12/12	12/31/17	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
13401	Nite-Hawk Sweepers LLC	Demonstrate Natural Gas-Powered Parking Lot Sweepers	08/28/13	05/31/16	90,000	200,000

Contract	Contractor	Project Title	Start Term	End Term	SCAQMD $	Project Total $
Infrastructure and Deployment (cont'd)						
14219	City of West Covina	Upgrade CNG Station at City Yard	05/15/14	06/15/17	200,000	618,429
14311	Southern California Gas Company	Install and Maintain CNG Fueling Station in Murrieta for SoCalGas	07/11/14	12/31/17	217,000	1,385,000
15438	United Parcel Service, Inc.	Refurbish/Upgrade Ontario UPS LCNG Infrastructure	12/31/14	06/30/18	246,707	484,535
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
Fuels/Emission Studies						
10722	University of California Riverside/CE-CERT	Re-Establish Testing Facility & Quantify PM Emission Reductions from Charbroiling Operations	08/06/10	03/31/16	60,000	60,000
13402	University of California Davis-Office of Research	Next Sustainable Transportation Energy Pathways (STEPS) Program	05/02/14	07/01/16	120,000	2,760,000
14162	National Renewable Energy Laboratory	Utilization of Fleet DNA Approach and Capabilities to Provide Vehicle Vocational Analysis in SCAQMD	02/26/14	06/30/17	174,985	199,985
15607	University of California Riverside/CE-CERT	Innovative Transportation System Solutions for NOx Reductions in Heavy-Duty Fleets	12/19/15	11/30/16	79,980	139,980
15623	University of California Riverside/CE-CERT	Ozone and SOA Formation from Gasoline and Diesel Compounds	10/02/15	06/30/16	75,000	480,338
15625	University of California Riverside/CE-CERT	Evaluate4 SOA Formation Potential from Light-Duty GDI Vehicles	10/02/15	06/30/16	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	02/14/17	170,000	270,000
Stationary Clean Fuels Technology						
10723	Eastern Municipal Water District	Retrofit Digester Gas Engine with NO_x Tech Aftertreatment Emission Control Technology	03/16/12	03/31/16	85,000	889,000
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
Health Impacts Studies						
12208	University of California Riverside/CE-CERT	Determine the Physical and Chemical Composition and Associated Health Effects of Tailpipe PM Emissions	01/21/12	01/31/16	175,000	1,375,000
12865	University of California Los Angeles	Develop Quantitative Cellular Assays for Use in Understanding the Chemical Basis of Air Pollutant Toxicity	06/08/12	07/31/16	368,457	368,457
14171	Southern California Research Center/Allergy & Asthma Associates of Southern California	Risk of Incident Asthma Among Children from In-Utero Exposures to Traffic Related Pollutants	09/22/14	03/21/16	99,670	317,119

Contract	Contractor	Project Title	Start Term	End Term	SCAQMD $	Project Total $
Health Impacts Studies (cont'd)						
14172	University of California Irvine	The Relation of Airway and Systemic Oxidative Stress to Particulate Air Pollution Exposures in an Elderly Cohort	02/17/14	08/16/16	159,974	376,368
Outreach and Technology Transfer						
00069	Walsh Consulting	Technical Assistance Relating to the Use of Alternative Fuels in Mobile Sources	02/17/00	02/28/16	35,000	35,000
05128	Mid-Atlantic Research Institute LLC	Development, Outreach & Commercialization of Advanced Heavy-Duty and Off-Road Technologies	08/08/05	03/31/17	70,000	70,000
07062	The Tioga Group, Inc.	Technical Assistance Related to Air Quality Impacts of Regional Goods	12/19/06	11/30/16	58,000	58,000
08210	Sawyer Associates	Technical Assistance on Mobile Source Control Measures and Future Consultation on TAO Activities	02/22/08	02/28/16	25,000	25,000
09252	JWM Consulting Services	Technical Assistance with Review & Assessment of Advanced Technologies, Heavy-Duty Engines, and Conventional & Alternative Fuels	12/20/08	06/30/16	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	05/31/16	75,000	75,000
12380	The Tioga Group	Technical Assistance Related to Emissions, Advanced Technologies and Goods Movement	04/13/12	04/30/16	25,000	25,000
12381	Integra Environmental Consulting Inc.	Technical Assistance Related to Emission Inventories, Goods Movement and Off-Road Sources	04/06/12	04/30/16	110,000	110,000
12453	Tech Compass	Technical Assistance with Alternative Fuels, Fuel Cells, Emissions Analysis and Aftertreatment Technologies	06/21/12	05/30/16	75,000	75,000
13194	Clean Fuel Connection Inc.	Technical Assistance with Alternative Fuels, Renewable Energy and Electric Vehicles	12/07/12	09/30/16	140,000	140,000
13198	Gladstein, Neandross & Associates, LLC	Technical Assistance with Alternative Fuels, Emissions Analysis and On-Road Sources	12/14/12	12/13/16	135,000	135,000
13408	University of California Irvine	Demonstrate Building Integration of Electric Vehicles, Photovoltaics and Stationary Fuel Cells	09/30/13	09/30/16	150,000	270,000
14185	Three Squares Inc.	Conduct Education Outreach for the Basin DC Fast Charging Network Project	04/11/15	10/31/16	89,183	89,183

Contract	Contractor	Project Title	Start Term	End Term	SCAQMD $	Project Total $
Outreach and Technology Transfer (cont'd)						
15344	Clean Fuel Connection, Inc.	Technical Assistance with Alternative Fuels, Electric Vehicles, Charging and Fueling Infrastructure and Renewable Energy	09/22/14	09/22/16	60,000	60,000
15369	Breakthrough Technologies Institute, Inc.	Technical Assistance with Low- and Zero-Emission Vehicles, Fuel Cells, Stationary Applications and Emissions Analysis	11/07/14	11/06/16	30,000	30,000
15380	ICF Resources LLC	Technical Assistance with Goods Movement, Alternative Fuels and Zero-Emission Transportation Technologies	12/12/14	12/11/16	30,000	30,000
15415	Gladstein, Neandross & Associates, LLC	Technical Assistance with Alternative Fuels and Fueling Infrastructure, Emissions Analysis and On-Road Sources	11/07/14	11/06/16	60,000	60,000
15507	Jerald Cole	Technical Assistance with Alternative Fuels, Emissions Analysis, and Combustion Technologies	01/09/15	01/08/17	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
15610	Goss Engineering, Inc.	Conduct Engineering Services at SCAQMD Headquarters	06/02/15	06/01/16	50,000	50,000
16055	University of California Irvine	Cosponsor Solar Decathlon – Develop and Demonstrate Solar-Powered House at 2016	11/05/15	02/29/16	50,000	730,000

Appendix C

Final Reports for 2015

SCAQMD Contract #08219 **June 2015**

Develop and Demonstrate Ten Plug-In Hybrid Electric Vehicles

Contractor
A123Systems (formerly Hymotion, Inc.)

Cosponsor
SCAQMD

Project Officer
Lisa Mirisola

Background

There has been increasing support for PHEVs from a wide array of organizations, including electric utilities, environmental groups, energy independence organizations, and other air districts. Several automobile manufacturers have also announced plans to investigate the technology but voice concerns about the battery durability in terms of calendar and cycle life.

Project Objective

At its November 3, 2006 meeting, the SCAQMD Governing Board approved RFP #P2007-14 to design, engineer, convert, test, certify, demonstrate, and maintain for 60 months 30 plug-in hybrid electric vehicles with supporting infrastructure at up to 15 demonstration sites in the South Coast Air Basin. At the March 2, 2007 meeting, the Governing Board awarded funding to A123Systems Inc. (formerly Hymotion, Inc.) to convert ten new Toyota Prius vehicles to plug-in hybrid electric vehicles using advanced nanophosphate lithium-ion battery systems and controls.

Technology Description

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

Status

CARB Executive Order D-647-1 issued September 8, 2008 limited sales of 500 units of A123 L5 BREM OVCC for 2004 – 2009 Toyota Prius. The L5 BREM OVCC conversion system includes a lithium-ion add-on battery pack, a current sensor, battery temperature sensors, and a controller. Two of the 500 units allowed were converted by local subcontractor The Dr. in Fountain Valley, California for this SCAQMD demonstration program, and delivered to SCAQMD August 7, 2009.

Figure 1: A123 Plug-In Hybrid Conversion

One of these converted vehicles was tested at a Chrysler facility in Michigan from July – November 2010, but was unable to prove compliance with new CARB requirements necessary for commercialization as an aftermarket product in California. No additional vehicles were converted for SCAQMD. A123 notified SCAQMD on January 18, 2011 that they abandoned the process for CARB certification and do not have resources to continue supporting this demonstration project with SCAQMD.

Results

Idaho National Lab compared fuel economy data from 180 A123 converted Prius (including one at SCAQMD) with stock Prius performance and found fuel efficiency improvement from 44 mpg to 49 mpg overall. Results are posted at http://avt.inl.gov/.

Figure 2: Data loggers were installed in the two converted vehicles and feedback on charging, trips, and current status were available from Gridpoint V2Green screens.

Benefits

The A123 converted plug-in hybrids' greatest value was as outreach tools to begin to educate the public and show the potential for plug-in hybrids before commercial plug-in hybrids were introduced in December 2010 by General Motors (Chevrolet Volt) and Toyota (Prius PHV).

Project Costs

The total cost for this project was $962,667 with SCAQMD cost-share not to exceed $622,667 and in-kind cofunding to be provided by Aerovironment ($100,000) for the fast-charging demonstration and from participating cities ($240,000) for Prius conversions. However, this project was terminated early and unspent funds totaled $497,667, which included all in-kind cofunding.

Commercialization and Applications

During the term of this contract, plug-in hybrid electric passenger vehicles have been commercialized by Ford, General Motors, Toyota, and many other automakers. The business case for aftermarket conversion of hybrid passenger vehicles to plug-in hybrid is not currently attractive for additional investment or commercialization. A123 declared Chapter 11 bankruptcy in 2012, and was purchased by Chinese auto supplier Wanxiang Group in 2013. After emerging from Chapter 11 bankruptcy in 2013, A123 refocused its business on low-voltage lithium-ion batteries used by automakers for weight savings and to power other MPG-lowering technologies. This is a diversion from its original plan of manufacturing large lithium-ion battery packs to power electric vehicles, though it still does that work for the Chinese market. In the low-voltage market, A123 supplies automakers such as Daimler AG with 12-volt starter batteries and 48-volt microhybrid batteries, which are used in various technologies.

SCAQMD Contract #11204 **November 2015**

Electric Conversion of Medium-Duty Fleet Vehicles

Contractor
AC Propulsion Inc.

Cosponsors
AC Propulsion Inc.
Comcast
SCAQMD

Project Officer
Brian Choe

Background
Medium-duty vehicles (8,500 to 14,000 pounds Gross Vehicle Weight Rating) are responsible for a disproportionate amount of emissions in the South Coast Air Basin (Basin). These vehicles account for 5% of the vehicle population, but are responsible for approximately 12% of the 2014 on-road mobile source NOx emissions according to the 2012 AQMP. Electrification of vehicles in this segment will provide considerable reductions in emissions with substantial benefits to the surrounding communities along their service routes. However, successful deployment of electric vehicles in this segment requires that specific vocations be properly matched to take advantage of their attributes. Hence, SCAQMD strongly supports demonstration of electric vehicles in a variety of vocations and duty cycles to identify matching applications and to promote commercialization of zero-emission transportation technologies.

Project Objective
AC Propulsion, a Southern California-based developer and manufacturer of electric vehicle propulsion systems, partnered with Comcast to develop and demonstrate medium-duty electric service vans to evaluate their viability in commercial service. The project was to convert three Comcast service vans to electric propulsion for demonstration in two stages. AC Propulsion converted a first prototype for a precursory evaluation by Comcast prior to converting the rest. Upon successful assessment of the prototype, AC Propulsion was to build the remaining two demonstration vehicles, addressing any deficiencies identified by Comcast.

Technology Description
The electric drive system developed by AC Propulsion was used to convert Ford E250 vans supplied by Comcast, utilizing a proprietary power electronics unit that maximizes efficiency over a broad operating range with regenerative braking capability. The propulsion system is powered by a 180 kW AC induction motor with a 41 kWh lithium-ion battery pack to provide an operating range of approximately 80 miles. The battery pack can be recharged in 7 hours with Level 2 and in 3.5 hours with a fast charger. The vehicles are also equipped with a Vehicle-to-Grid interface to charge back to the grid during emergencies or high-demand charge periods.

Comcast Electric Service Van

Status
AC Propulsion completed conversion of all three Comcast service vans to EVs but experienced delays in the deployment of the vehicles due to coordination challenges with project partners. Despite the delay, the electric vans were finally deployed in commercial service but they were not operated as planned. This was largely due to the fact that Comcast changed their operation mode from maintaining the vehicles at a central location to allowing drivers to take them home after their shifts. Without EVSEs to charge the vehicles at home, the drivers opted to switch back to conventional service vans and the electric vehicles were left unused. AC Propulsion has sought other

partners to demonstrate the electric vans without any success. As a result, AC Propulsion requested to terminate this project in November 2015.

Results

As requested by AC Propulsion, this project is terminated without having completed vehicle demonstration in commercial service. However, AC Propulsion intends to continue investigating options to repurpose these vehicles in related projects and is currently in discussion with University of Delaware to use them in a vehicle-to-grid study program.

Benefits

Electrification of medium-duty vehicles, including service vans and delivery trucks, will help to advance electric and hybrid technologies in transportation sectors, providing substantial reductions in both criteria pollutants and greenhouse gases.

Project Costs

The total project cost was initially estimated at $755,767 with SCAQMD funding $300,000, with the remaining $455,767 cost-shared between AC Propulsion ($355,767) and Comcast ($100,000). Since the project was terminated without having completed vehicle demonstration, SCAQMD retained $75,000 of the $300,000 award.

Commercialization and Applications

Although the project was terminated without field demonstration, a prototype has been successfully tested by Comcast with positive feedback. AC Propulsion plans to continue development and refinement of the electric drive system with a goal to ultimately commercialize the system or its components.

SCAQMD Contract #12862 **April 2015**

Develop and Demonstrate Class 8 Drayage Plug-In Hybrid Heavy-Duty Vehicle

Contractor
Volvo Technology of America & Volvo Group

Cosponsors
Volvo Technology of America, Inc.
U.S. DOE
SCAQMD

Project Officer
Joe Impullitti

Background
To attain federal ozone standards and to reduce the adverse health impacts of near-road emissions along freight corridors in the South Coast Basin, SCAQMD co-sponsors development and deployment of advanced clean cargo transport technologies.

Project Objective
The objective of this project was to develop, build and demonstrate a prototype Class 8 heavy-duty plug-in hybrid drayage truck with significantly reduced emissions and fuel use.

Technology Description
The truck features a 6x2 Mack chassis at 60,000 gross combination weight (GCW) with the proprietary hybrid driveline, a new energy-optimized battery, external charging interface and newly developed energy management and control systems suitable for port drayage application. Using hybrid trucks for drayage application (and other local and regional haul applications) can reduce emissions and lowers fuel use significantly. By utilizing plug-in hybrid technology, fully zero-emission electric mode is possible for limited distances at low speeds, such as in a predetermined zero-emission geofence. The integration of a plug-in hybrid powertrain with downsized engine (11L in lieu of 13L), along with several improvements to the complete vehicle efficiency are expected to add up to approximately 30% improvement in fuel economy in a drayage cycle containing a mix of the driving patterns described in the report "Characterization of Drayage Truck Duty Cycles at the Port of Long Beach and Port of Los Angeles." Using clean electricity from the Southern California grid to externally recharge the hybrid battery and offset the least efficient operating points of the engine is also expected to result in approximately 30% reduction of greenhouse gas (GHG) emissions.

Status
The project delivered a working prototype plug-in hybrid truck along with a first evaluation of the efficiency and emission potentials of the technology. The project was completed in July 2015 with a final demonstration of the concept vehicle on a simulated drayage route around Volvo's North American headquarters in Greensboro, NC. The route included all traffic conditions typical of drayage operation in Southern California as well as geofences defined to showcase the zero-emission capabilities of the truck. The demonstrator successfully completed four consecutive trips with a gross combined vehicle weight (GCVW) of 44,000 lb., covering approximately 2 miles out of a total distance of 9 miles per trip in the Zero Emission (ZE) geofence. The final report is on file with complete technical details of the project. The only unanticipated problems encountered during the project were delays in the vehicle retrofit due to premature failures of critical prototype components, which required a 7-month no-cost extension to the original contract.

Demonstration Drayage Truck Loading a Container

Results

This vehicle is expected to use approximately 30% less fuel than a typical drayage truck in daily operation, and it is designed to allow full electric operation whenever operating in a marine terminal in the ports of Los Angeles / Long Beach.

This project took a well-to-wheels approach in order to estimate the greenhouse gas (GHG) emissions from drayage vehicles. The CO2 equivalent emissions from the grid power were obtained from the [eGRID] database. Since this vehicle is to be used in the Los Angeles Port area only, the values of CO2 equivalent emissions from the [eGRID] database are equal to 0.339Kg/KWH. The CO2 equivalent emissions from one gallon of diesel fuel are 12.725Kg/gallon. Based on these numbers we estimated that drayage PHEV usage will result in GHG emission reduction of approximately 25%, which is in line with the initial project goals.

Even though we weren't able to complete detailed simulations of tailpipe emissions for this concept truck, our general prediction is that the overall NOx output, measured in units of volume or weight per mile, will be reduced drastically but that the NOx emissions measured in g/bhp-hr may initially increase in such a PHEV as compared to a conventional vehicle. The overall emission reduction is a result of the much lower fuel use, but multiple factors can lead to a potential increase in brake specific emissions: the frequent restarts of the engine are a new challenge when it comes to controlling engine-out emissions, and cooling down of the engine and aftertreatment components during zero-emission operation can result in lower average NOx conversion levels in the SCR system; depending on how the hybrid driveline is controlled, the engine could operate in higher brake specific NOx output load points more frequently than the equivalent conventional powertrain.

Our future work will therefore focus on improving our analytical tools to better capture engine and exhaust aftertreatment component behavior under start-stop or low-speed conditions. We believe that this will help identify robust strategies to control the complex plug-in hybrid energy management algorithms in order to maximize the emissions and energy benefits of the vehicle compared to its baseline.

Benefits

This project demonstrates new complete-vehicle solutions that can offer significant benefits when applied to a specific vehicle application.

The customer truck data collection performed during this project to create a detailed drayage duty cycle with accurate altitude and performance metrics was critical to ensure that the system simulations could guide the selection of most suited concept and provide representative insight in emission reduction potential. We will be publishing this detailed duty cycle, along with observations and recommendations regarding improvement opportunities, to aid other projects focusing on improving the emissions and fuel use of drayage trucks in the ports of Los Angeles and Long Beach.

As a result of work performed in this project an invention was filed to the U.S. Patent Office: PCT/US2015/026009 (Weight based aerodynamic deflector control).

Project Costs

This project was completed on target with a total cost of $2.4M as follows:

Funding Partner	Funding Amount	Funding Percent
SCAQMD	$216,000	9%
U.S. DOE	$984,000	41%
Volvo Technology of America, Inc.	$1,200,000	50%
Total	**$2,400,000**	**100%**

Commercialization and Applications

This project supported the submission in 2013 of a new proposed standard for charging interface of heavy vehicles: SAE J3068. The concept truck showcases components included in this proposal. The technical sub-committee had made significant progress at the time of writing of this report, with several key players represented in the area of electrification across North America.

SCAQMD Contract #13042 **May 2015**

Demonstrate Full-Speed Battery Electric Vehicles

Contractor
South Bay Cities Council of Governments (SBCCOG)

Cosponsor
SCAQMD

Project Officer
Lisa Mirisola

Background
Achieving federal and state clean air standards, as well as reducing greenhouse gas emissions to meet climate action goals in Southern California, will require emission reductions from both mobile and stationary sources, passenger cars and light trucks that account for most of these emissions. New zero-emission technologies such as slow-speed Neighborhood Electric Vehicle (NEVs) and full-speed Battery Electric Vehicles (BEVs) have been proposed to meet these sustainability goals and to reduce dependence on petroleum products used to fuel internal combustion engine (ICEs) vehicles. For many residents within the geographic boundaries of the SCAQMD, many trips and even commutes are relatively (five miles or less) local and can be accomplished with the replacement of an ICE vehicle with either an NEV or BEV into a household vehicle fleet.

Project Objective
This follow-on local-use vehicle (LUV) program entitled "Drive the Future" was intended to complement SBCCOG's NEV study through an examination of the household use and market of full-speed BEVs to residents, businesses and municipalities in the South Bay sub-region. The project objective was to answer these three questions:

1. Are BEVs sufficient to meet the mobility and transportation needs of South Bay residents?
2. Does the usage have the potential to produce significant environmental and economic benefits?
3. What policies and initiatives can accelerate the market for BEVs?

Technology Description
Battery electric vehicles are full-sized, freeway speed, zero-emission automobiles powered by a stored on-board battery pack; all BEVs are range limited by the size and number of the battery packs that are designed for each vehicle. The range of BEVs varies from the sub-category of slow-speed NEVs, that can travel up to 25 total miles per charge, to mid-range BEVs whose range is approximately 80 to 100 miles, to long-range BEVs with a range of greater than 200 miles. The BEVs tested in the study were mid-range and had approximately 80 miles of range.

One of four BEVs Used in Study

BEVs must be plugged-in to some sort of electrical outlet for recharging. All BEVs can be charged using a common household outlet – Level 1 (110v), as well as Level 2 (220/240v) outlets available through charging networks throughout the region. Some BEVs are also outfitted with an adaptor that allows for Level 3 (440 or DC fast charging). The time required to re-charge varies by type of charging with Level 1 taking the longest time; Level 2 about half as long as Level 1; and DC 3 fast charging significantly faster to charge than Level 2 (approximately 20 minutes to recharge from zero to eighty percent battery capacity.)

Status
The active demonstration phase of the project was completed in January 2015. There were four main activities: 1) preparation (leasing vehicles, arranging insurance, acquiring and installing GPS, recruiting, and selecting and training participants);

2) active demonstration (47 households drove a BEV for up to 2 months per household); 3) data processing and analysis (GPS generated a data point every minute each vehicle was "on" creating millions of geo-data points that were mapped, summarized in tables and interpreted); and 4) reporting. Unanticipated problems included occasional unreliability of the GPS system used to track some vehicles which led to changes in installation protocol; poorly maintained driver logs which required additional staff time to call drivers for interpretation; and complex travel patterns and destinations which required more staff time to interpret and analyze.

Results

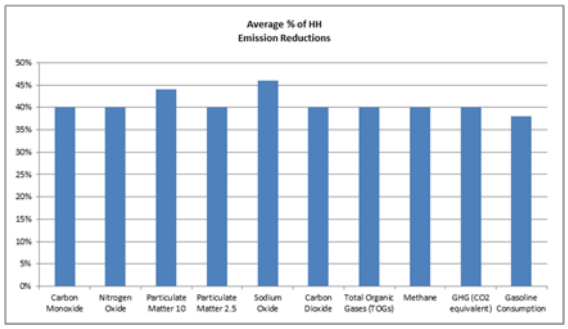


Table 1: Average Household BEV Emissions Reductions

The objectives did not involve any specific emissions reduction targets. However, emissions reduction per household is one outcome the project sought to measure; the resulting average household reductions in criteria pollutants and GHG emissions were high compared to reasonable expectations.

The study also revealed that the addition and use of a BEV to a household could meet most household mobility needs (including commuting to work). The NEV findings demonstrated that around 19% of household gas-powered vehicle miles traveled (VMT) could be replaced by an NEV. Because BEVs are longer range, they are able to account for 38% of household VMT. Aside from the relative difference in range as compared to their ICE vehicles, there were no performance tradeoffs in mobility.

Benefits

Immediate benefits include replacing 2,180 gallons of gasoline, reducing participants 'pump' costs by $8,720, and reducing most pollutants by 40%.

Potential benefits include giving BEVs a high level of public exposure, while documenting environmental impacts and customer responses that can help make this vehicle market strategically attractive to original equipment manufacturers (OEMs) and policy makers.

Potential benefits also include expanding the BEV market in order for more households to reduce gasoline consumption, CO2, particulate matter, carbon monoxide and carbon dioxide emissions by up to 40% over current gas-powered vehicles.

Project Costs

Project costs totaled $512,545, with SCAQMD's contribution at $320,000.

	Actual Cost (Including in-kind by SBCCOG)	**SCAQMD Project Budget**
Total	$512,545	$320,000
Labor	$385,112	$190,452
GPS	$16,000	$16,466
Insurance	$22,003	$19,082
Vehicle Acquisition	$85,796	$94,000
Vehicle Unplanned	$1,014	$0
Other Expenses	$2,620	$0

Table 2: Project Cost Breakdown

Commercialization and Applications

The SBCCOG will post the report on its website, make presentations to the electric drive industry, South Bay cities, and offer them to SCAG, L.A. Metro and governmental entities such as the Strategic Growth Council and the California Air Resources Board.

There are about 275,000 "secondary" vehicles driven by South Bay residents. Presenting viable options to replace them with BEVs or NEVs is the market target. To accomplish that, a public education initiative to "right size" vehicle choices is planned.

SCAQMD Contracts #13418, et al. **December 2015**

SoCalEV Ready EV Charger Installations

Contractor
Various SoCalEV partner organizations

Cosponsor
SCAQMD
CEC

Project Officer
Patricia Kwon

Background
The Southern California Regional Plug-In Electric Vehicle Plan (SoCalEV) is a regional collaborative among cities, utilities, automakers, local and regional government agencies, businesses and others in the region who are actively engaged in supporting and building the necessary infrastructure for the commercial launch of electric vehicles. The SoCalEV Ready project was funded by a CEC grant to deploy 319 Level 2 electric vehicle (EV) charging stations throughout the South Coast Air Quality Management District in all four counties. These chargers were deployed starting in 2013, with all installations completed no later than April 2016.

Project Objective
Under multiple contracts or memorandums of agreement (MOAs) executed with SoCalEV partners, these chargers are sited at local government agencies, universities, hospitals, and cultural destinations to create greater availability of public charging infrastructure. Installations were performed either by SoCalEV partners or contracted installers with experience in commercial installations. CEC funds were used for a portion of the costs associated with hardware and/or installation, and SoCalEV partners used their own funds as required cost sharing (39%) for the CEC grant to pay remaining costs. SoCalEV partners that completed their installations include the Cities of Claremont, Covina, Lake Elsinore and Palmdale; County of Los Angeles; California State University campuses at Fullerton, Long Beach, Los Angeles, and San Bernardino; California Polytechnic Pomona; and University of California Irvine.

Figure 1: Los Angeles Zoo, DCFC and Level 2 EVSE

Figure 2: City of Palmdale Level 2 EVSE

Technology Description
EV charging stations were commercially available technology including Level 2 (240V) charging stations with SAE J1772 connectors and DC (480V) fast charging stations with CHAdeMO and SAE Combo connectors. These connectors worked with all of the EVs available on the market: all EVs can use the J1772 connector for Level 2 charging. Japanese EVs use the CHAdeMO connector while American/European EVs use the SAE Combo connector for DC fast charging.

Figure 3: Leo Carrillo State Park Level 2 EVSE

Status

The majority of installations have been completed by December 2015. SoCalEV partners are providing charger utilization data and documenting lessons learned on this project. CEC sent a program evaluator in November 2015 to visit a dozen sites to confirm charger performance and high level of utilization. The MOAs under this project are as follows:

SoCalEV Partner	Contract #
City of Claremont	13418
California State University Los Angeles	13419
University of California Irvine	13420
County of Los Angeles	13421
City of Santa Monica	14074
City of Covina	14095
University of California Santa Barbara	14153
Clean Fuel Connection, Inc.	14199
Cal State University San Bernardino	14201
City of Palmdale	14207
City of Lake Elsinore	14208
Cal State Polytechnic University Pomona	14209
Cal State University Long Beach	14210
Cal State University Fullerton	14236

Results

Data on the chargers is being collected and will be included in a final report to CEC due in April 2016. An example of charger utilization data provided by SoCalEV partners includes Table 1 below for chargers installed at California State University Los Angeles.

Table 1: Charger Utilization at CSULA

Benefits

This project was important in increasing the deployment of public charging infrastructure at a variety of locations. It has also assisted in making EV infrastructure more visible to the general public and significantly increasing the electric range of EVs to allow for longer and more frequent trips and vehicle miles traveled.

Project Costs

The CEC grant provided funding towards hardware and/or installation in the amount of $840,750 with SoCalEV partners providing additional cost sharing in the amount of $542,659. Total project costs were $1,383,409. In addition to the 319 funded installations, SoCalEV partners took the opportunity to install additional Level 2 charging stations. Two DC fast charging stations were installed at the Los Angeles Zoo and Los Angeles International Airport through a partnership with Los Angeles Department of Water and Power and Adopt a Charger.

Commercialization and Applications

Level 2 and DC fast charging stations are fully available commercial technologies which have been and will continue to be deployed for a variety of purposes including residential, public, workplace, and destination charging. This deployment project assisted in accelerating the availability of public charging infrastructure which is much needed to go beyond the early adopter stage and have the technology embraced by the general public.

SCAQMD Contract #10046 **November 2015**

Develop and Demonstrate Renewable Hydrogen Energy and Fueling Station

Contractor

Air Products and Chemicals, Inc. (APCI)

Cosponsors

California Air Resources Board
FuelCell Energy, Inc.
Orange County Sanitation District (OCSD)
SCAQMD
Southern California Gas Company
U.S. Department of Energy

Project Officer

Joseph Impullitti

Background

The implementation of zero-emission vehicles is a key component in the effort to attain air quality standards in the South Coast Air Basin. The production and use of renewable hydrogen in fuel cell vehicles will be keys to meeting goals for reducing emissions of both criteria pollutants and greenhouse gases.

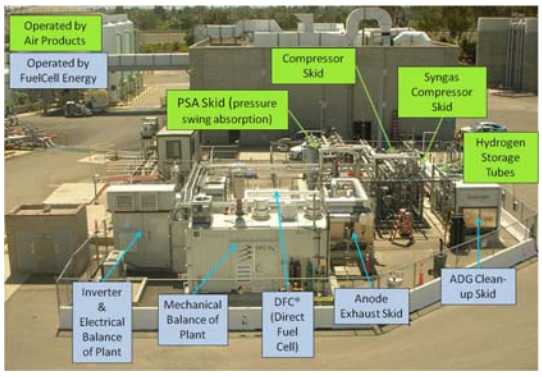
Project Objective

SCAQMD provided cost-sharing to augment U.S. DOE and CARB funding awarded to Air Products and Chemicals, Inc. (APCI) to construct, install and operate a first-of-a-kind Hydrogen Energy Station, which would use a high-temperature fuel cell to coproduce hydrogen and electricity generated from anaerobic digester gas at the Orange County Sanitation District (OCSD) facility in Fountain Valley, CA. Electricity would be returned to the host site, and hydrogen would be sent to a publicly accessible hydrogen fueling station. Development of the Hydrogen Energy Station which was deployed at OCSD was funded under a U.S. DOE Cooperative Agreement (DOE $5,950,000, non-federal $6,590,000), which included a stage-gate approach involving steps of concept feasibility, preliminary system design, and detailed engineering design/construction/shop validation.

Technology Description

Digester gas from the wastewater treatment plant is first cleaned and conditioned before being fed to the Hydrogen Energy Station, which incorporated FuelCell Energy's Direct Fuel Cell (DFC®) technology. The DFC® unit is a molten carbonate-based fuel cell system capable of simultaneously reforming hydrocarbon feedstocks to syngas (hydrogen, CO and CO_2), while producing power and process heat. The fuel cell is designed to produce 300 kW without hydrogen coproduction and 250 kW along with 100 kilograms per day of hydrogen.

The syngas produced by the DFC® is further processed into purified hydrogen using APCI's pressure swing adsorption process. Purified hydrogen is then supplied to the hydrogen fueling station, which includes compression and storage systems sized for the 100 kilograms per day production rate (which can serve 20 to 30 cars per day). APCI's proprietary fueling protocol (of which four patents are cited in the SAE hydrogen fueling TIR J-2601) is utilized to cascade fill from the storage tubes to the vehicles. The station utilizes two dispenser hoses (one at H35/5,000 psi pressure and one at H70/10,000 psi pressure). The H70 gas is cooled to temperatures approaching -40 degree C so that refueling times of 3 to 4 minutes can be achieved.



Hydrogen Energy Station at OCSD

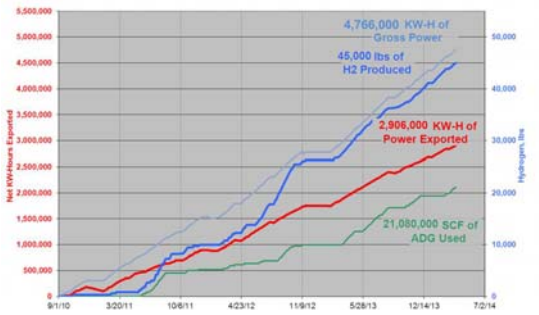
Status

SCAQMD joined the project in December 2009 during site engineering efforts. Site construction was completed in July 2010, and the Hydrogen Energy Station was shipped from FuelCell Energy's facilities in Danbury, CT, where the system had undergone over 8,000 of shop validation testing. Initial operation of the Hydrogen Energy Station on natural gas began on September 13, 2010, reaching a rate 300 kW net AC power on September 20, 2010, as part of the fuel cell's power conditioning process. The hydrogen purification system underwent its first test at 50% rates on September 23, 2010. The hydrogen fueling station was also installed in the fall of 2010, with the dispenser sited adjacent to an existing CNG dispenser located in the entry area to the OCSD facility. Commissioning of the hydrogen fueling station took place in March 2011, with the digester gas clean-up system installed in May 2011. Clean digester gas was first generated on May 25, 2011, and the three-year operating program was completed on May 31, 2014. At the same time auto manufacturers began rolling out their production fuel cell vehicles, SCAQMD and CARB determined there would be a strong need for hydrogen to support the fleet of new hydrogen-powered vehicles so the two agencies pooled their funding to continue operating the station, using delivered hydrogen, through September 2015. Using funding from other sources APCI will continue its operation serving fuel cell vehicle customers through October 2016.

Results

Power quality issues were encountered at the site from the initial commissioning of the Hydrogen Energy Station through early 2012; these were resolved as a result of efforts by OCSD and the National Fuel Cell Research Center at the University of California, Irvine (UCI), which was responsible for data analysis and education and outreach under the CARB program.

Other key performance results include efficiency (greater than the target value of 50%), performance of the digester gas clean-up system (no breakthrough of contaminants to the fuel cell), and emissions at 5% of the 2007 CARB limit for NOx and < 1% of the limit for CO. Use of the hydrogen fueling station increased over time, reaching an average of 5 fueling events per day in early 2014. This average continued through the end of the project, with 860 fueling events from July to November 2015.



Three-Year Operation Results

Benefits

Deployment of fuel cell electric vehicles (FCEVs) is a key element toward achieving goals to reduce levels of criteria pollutants in the South Coast Air Basin. Manufacturers of FCEVs have provided survey figures to state agencies indicating their plans to deploy tens of thousands of light-duty cars into the South Coast Air Basin in the 2015-2107 timeframe. In order to meet this goal, reliable hydrogen fueling stations are needed to provide confidence to automakers and their potential customers. Local, reliable sources of renewable hydrogen will be needed to meet state requirements for renewable energy content, and demonstrations of technologies such as the Hydrogen Energy Station are necessary to provide operating data for scale-up to MW scale power production with its corresponding hydrogen coproduction that are expected to achieve the target economics for both major products.

Project Costs

Original project costs were $8,436,735, as follows: CARB, $2,700,000; U.S. DOE, $2,077,284; SCAQMD, $750,000 (9%); FuelCell Energy, $51,979; and APCI, $2,857,472. However, CARB and SCAQMD augmented this funding ($200,000 and $75,000, respectively) to continue station operation through November 2015 under this contract.

Commercialization and Applications

Demonstration testing of fueling station equipment and novel hydrogen production systems at relevant usage rates is critical to gain the learnings necessary for rollout of hydrogen refueling infrastructure to the general public. In addition, APCI and FuelCell Energy are seeking to develop project opportunities to utilize the next product platform for the molten carbonate fuel cell (1.4 MW) which could be configured for hydrogen coproduction.

SCAQMD Contract #10061 **January 2015**

Maintenance and Data Management for the SCAQMD Hydrogen Fueling Station

Contractor
Hydrogenics Corporation

Cosponsor
SCAQMD

Project Officer
Larry Watkins/Lisa Mirisola

Background
The implementation of zero-emission vehicles (ZEVs) and related infrastructure is a key component in the effort to achieve healthful air quality in the South Coast Air Basin. Fuel Cell Vehicle (FCV) technology is emerging at an accelerated pace and related hydrogen fueling infrastructure will play a crucial role in this effort

Originally constructed by Stuart Energy, the subject fueling station produced hydrogen from on-site electrolysis and has been operational at SCAQMD in Diamond Bar, CA, since 2004. Hydrogenics Corporation (Hydrogenics) acquired Stuart Energy in 2005 and took responsibility for station maintenance.

Project Objective
Hydrogenics maintained the hydrogen fueling station in Diamond Bar, California (see Fig. 1) to provide 5,000 psi (350 Bar) hydrogen for hydrogen-fueled Prius vehicles developed under the Five-Cities demonstration project 04185 which has been completed, as well as fuel cell vehicles from Honda, Mercedes, and Toyota used in SCAQMD's demonstration fleet.

Technology Description
The station was designed to produce 24 kg/day, with storage at 6250 psi. Hydrogen was dispensed from an FTI International Group, Inc. dispenser by SCAQMD staff and other drivers trained by Stuart and/or Hydrogenics. Access was controlled by PIN codes.

Status
This contract term was 10/30/09 to 1/31/15. Maintenance and management services included 1) Train designated SCAQMD staff in the proper use of the fueling dispenser, card-lock system and vehicle fueling procedures; 2) Repair unsafe or inoperable equipment or parts of the fueling system as needed; 3) Provide fueling and summary station use reports.

The station was decommissioned in 2014, and all above-ground equipment was declared obsolete and/or compressor oil contaminated and removed by Hydrogenics, except for two items which SCAQMD designated for reuse. The FTI dispenser was provided at no cost to Sunline Transit to use as spare parts for the only other remaining identical FTI dispenser known to SCAQMD to extend the life of their fueling station. The hydrogen storage tubes were retained at SCAQMD in the hopes that they could be reconditioned and reused for upgrading our CNG station.

Figure 1: Hydrogen Station at SCAQMD

Results
From 2005 through 2013, this hydrogen station was used a total of 3223 times and dispensed a total of 4,035 kilograms (+/- 10%) of hydrogen. Maintenance of the stations was manageable and rarely caused disruption to the passenger vehicle users. Annual usage was reported 2009 – 2013 (see Table 1).

Year	H2 Dispensed (Kg)	Fills
2009	465	362
2010	97	74
2011	166	137
2012	122	87
2013	81	57
TOTAL	**931**	**717**

Table 1: Hydrogen Dispensed 2009 - 2013

In 2010, an electrical panel malfunction resulted in shutdown of the station, with no injuries. As a precaution, hydrogen pressure in storage was slowly reduced to about 200 psi, but no other damage was found in the system. The manufacturer of the gas control panel had gone out of business. However, Hydrogenics manufactured control panels superior to the defunct panel and installed one at SCAQMD.

The production capacity of the electrolyzer was reduced to about 12 kg/day in 2010 to extend the life of the fueling station until the SCAQMD site was scheduled for upgrade.

Benefits

This station was recognized by CARB as the first station in Southern California designed for passenger cars on the new hydrogen highway network in California.

This project was an important step toward the use of renewable energy sources, particularly hydrogen. The installation of the station allowed SCAQMD to monitor the fueling patterns and witness how a hydrogen fueling station is maintained. The project provided important lessons learned on station operation and maintenance costs which can be applied to future commercial stations serving light-duty FCVs.

Project Costs

The total cost of this contract was $468,000, fully funded by the Clean Fuels Fund. Some in-kind costs were absorbed by Hydrogenics.

Commercialization and Applications

This hydrogen fueling station was designed to support a small fleet of vehicles (fewer than 10 cars) operating at 350 bar tank pressure. The current generation of FCVs requires 700 bar hydrogen pressure to achieve the desired range for consumer acceptance.

Deployment and operation of this station with others in California led to greater commitments of FCVs, with additional public funding for hydrogen stations in California.

Hydrogenics is a member of the California Fuel Cell Partnership and has over 60 years of experience designing, manufacturing, building and installing hydrogen systems. Hydrogenics recently supplied a new 65 kg/day electrolysis system with project partners for CSULA (see Fig. 2).

Further reduction in cost and additional technical improvements are needed to scale-up hydrogen fueling as additional fuel cell vehicles are introduced.

Figure 2: Hydrogen Produced with Hydrogenics Electrolysis System at CSULA

SCAQMD Contract #13259 **March 2015**

"Five Cities" Program to Demonstrate Hydrogen Fueling Station Operation and Maintenance

Contractor
Air Products and Chemicals, Inc. (APCI)

Cosponsor
SCAQMD

Project Officer
Larry Watkins/Patricia Kwon

Background

The implementation of zero-emission vehicles (ZEVs) is a key component in the effort to achieve healthful air quality in the South Coast Air Basin. Fuel Cell Vehicle (FCV) technology is emerging at an accelerated pace and related fueling infrastructure will play a crucial role in this effort.

Project Objective

Under Contract #05165, SCAQMD allocated a total of $3.89 million towards funding the "Five Cities" Program for the installation and operation of a network of five hydrogen fueling stations throughout the Basin to support the operation of FCVs and electric-hybrid internal combustion engine vehicles converted to use hydrogen as the fuel. Contract #13259 extended the Program to support continued operation and maintenance.

Figure 1: Santa Ana Mobile Fueler Station

Figure 2: Riverside Electrolyzer Station

Technology Description

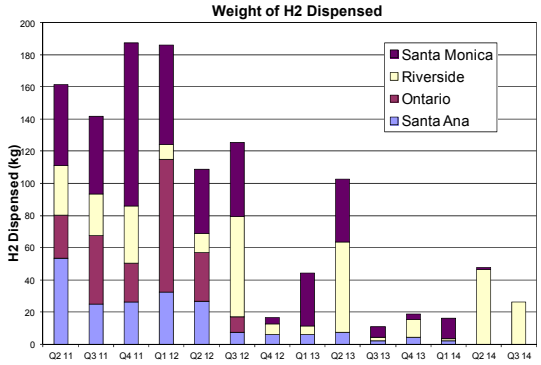
During the initial five-year period of performance, Air Products designed, built and installed stationary fueling sites supplied by an integral proton exchange membrane (PEM) electrolyzer system for Riverside, Burbank and Santa Monica, and a self-contained, transportable fueling unit that was refilled at an APCI hydrogen production facility for the Santa Ana and Ontario sites. These stations were supplied in support of the SCAQMD "Five Cities" Program to fuel hydrogen ICE and fuel cell vehicles in the South Coast Air Basin.

Status

The Burbank station concluded its participation in the demonstration program in 2009 as part of a station upgrade and was not included under this maintenance and operation contract; however, it continues to operate today under another operator. The mobile fueler in Ontario completed participation in 2012 and the mobile fueler in Santa Ana in May 2014. The stations at Santa Monica and Riverside completed participation in 2015. A station is planned at a retail location within two blocks of the Santa Monica site and recent plans were announced to upgrade the Riverside station.

Results

From March 2011 through September 2014, the hydrogen fuel stations were used a total of 885 times and dispensed a total of 1,267 kilograms (+/- 10%) of hydrogen. Maintenance of the stations was manageable and rarely caused disruption to the users.



H2 Dispensed Mar2011-Sep2014

Benefits

This project was an important step toward the use of renewable energy sources, particularly hydrogen. The installation of the projects allowed SCAQMD to monitor the fueling patterns at each of the sites and witness how a hydrogen fueling station is run. The projects have successfully demonstrated the use of electrolysis, which if supplied with a renewable source of electricity, is a clean way to produce hydrogen. The project provided important lessons learned on station operation and maintenance costs which can be applied to future commercial stations serving light-duty FCVs.

Project Costs

The total contract value, fully funded by the SCAQMD, for this follow-on maintenance and operation contract to provide continued support of the "Five Cities" Program was $390,000. No additional costs beyond hydrogen delivery costs (for the Santa Ana station) and station maintenance costs (for Riverside and Santa Monica) were encountered.

Commercialization and Applications

The stations in the "Five Cities" Program were all designed to support small fleets of vehicles (less than 10 cars) operating at 350 bar tank pressure. The current generation of FCVs requires 700 bar hydrogen pressure to achieve the desired range for consumer acceptance. Station designs have been developed using both delivered hydrogen *and* onsite production via electrolysis that dispense at 700 bar and provide a renewable fuel to the customer.

Deployment and operation of the Stations led to greater acceptance of FCVs as demonstrated by upgrades or additions of 700 bar hydrogen stations.

Given the challenges for deployment of early-market light-duty vehicle fueling infrastructure, the "Five Cities" Program provided important lessons learned on station costs, production/supply modes and customer feedback. Public and private stakeholders have used this information to develop follow-on plans for the future which include the rollout of 100 hydrogen fueling stations in the California market over the 2013-2023 timeframe.

SCAQMD Contract #13400 **December 2015**

Develop Hydrogen Network Investment Plan and Assess Policies and Incentives for Implementation

Contractor

Energy Independence Now (EIN)

Cosponsors

SCAQMD
Energy Foundation
CARB
California Fuel Cell Partnership
Toyota
Emmett Foundation
Andrew Sabin Family Foundation
Daimler
Patagonia

Project Officer

Larry Watkins & Patricia Kwon

Background

Hydrogen fuel cell electric vehicles (FCEVs) represent a crucial component of the State of California's strategy to meet federal air quality standards and state zero emission vehicle and greenhouse gas (GHG) emissions targets. [1] The substantial emissions benefits associated with FCEVs can only be realized if sufficient hydrogen fueling infrastructure is available to support these vehicles.

EIN, in partnership with SCAQMD, embarked on a project to develop a Hydrogen Network Investment Plan (H2NIP) in order to examine market success factors relative to the looming launch of FCEV vehicles and support infrastructure. The project was broken into two phases. Phase I focused on pre-commercial market dynamics relating to infrastructure and Phase II focused on fuel incentives and market dynamics for renewable hydrogen.

Phase I Project Objectives

This phase was created to develop a consensus-based H2NIP that delineates key actions needed to facilitate a successful market launch of hydrogen FCEVs. The goal was to create a common platform for stakeholders to identify, demonstrate and justify options to optimize incentives for hydrogen fueling stations as well as establish network level policies to ensure stations remain open and growth can be sustained.

Phase I Status

The final version H2NIP was completed in October 2013. It is publically available on EIN's website and is currently serving as a resource for multiple state agencies.[2]

Phase I Results

The H2NIP establishes a baseline understanding of current pre-commercial market dynamics. As an example, Figure 1 below illustrates market risk assumed by the first 68 fueling stations. If these baseline stations were in place by 2017, and FCEV market uptake is slow (1/4 of CARB's ZEV Likely Compliance Scenario is shown here), many stations would be under-utilized for years – a recipe for sustained negative cash flows.

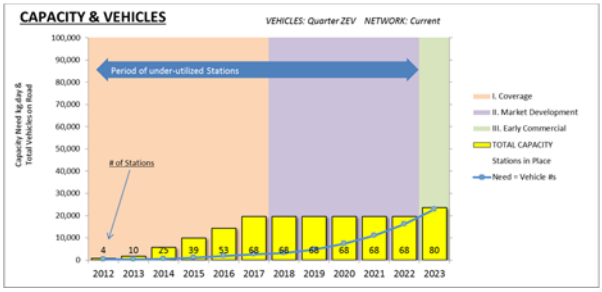


Figure 1: Market Risk

The baseline understanding of the current market serves as the foundation for a series of 15 recommendations aimed at overcoming the challenge associated with deploying a new infrastructure system. Critical near-term recommendations focus on building marketplace certainty and providing the risk protection needed to motivate early market investment to establish the baseline coverage network.

[1] See US Clean Air Act, California's Global Warming Solutions Act (AB 32), CARB's ZEV Regulation, and Executive Order B-16-2012

[2] http://www.einow.org/images/stories/factsheets/h2nip_full_paper_final.pdf

In addition to the recommendations established in the H2NIP report, EIN developed a robust Microsoft Excel-based H2NIP Model to test the impact of a variety of incentives and market scenarios on a station investor's (both public and private) bottom line.

Phase I Costs

A small portion of funding from Phase I to develop the H2NIP were carried over to fund the beginning of the implementation phase. Approximately $10K of this funding was deployed at the end of 2012. This funding matches what EIN planned at the onset of the project.

Phase I Cost-Share (Actual)	
SCAQMD	$50K
Energy Foundation*	$27K
CARB	$25K
CaFCP	$25K
Toyota	$25K
Emmett Foundation*	$20K
Daimler	$15K
Sabin Foundation*	$15K
Patagonia*	$8K
Total	**$210K**
**EIN Donors*	

Phase II Project Objectives

This phase was created to develop an assessment of fuel incentives and renewable hydrogen in California that delineates findings on hydrogen-related environmental credits, outlines key actions needed to further develop California's Low Carbon Fuel Standard (LCFS) and U.S. EPA's Renewable Fuel Standard (RFS) incentives and to highlight context, concern and drivers for the renewable hydrogen market. LCFS program credits are issued to promote a 10% reduction in carbon intensity of the state transportation fuel mix by 2020, while RFS credits are issued to renewable fuel producers to reduce GHG nationwide.

Phase II Status

The final version of the plan, 'Crediting Hydrogen: Fuel Incentives and Renewable Hydrogen Investment in California' was completed in November 2014. It is publically available on EIN's website and is currently serving as a resource for multiple state agencies.[3]

Phase II Results

EIN worked to investigate the current barriers and opportunities associated with the LCFS credits and renewable hydrogen requirements (SB 1505) and propose recommendations to the hydrogen and fuel cell community on ways to address them.

Work included the briefing paper 'Crediting Hydrogen: Fuel Incentives and Renewable Hydrogen Investment in California'; presentations highlighting findings and eliciting feedback and input on priorities, including detailed financial analysis of the projected values of LCFS credits, as described in the CaFCP 2014 work plan; and meetings to discuss findings and the viability of options to facilitate LCFS and SB 1505 streamlining.

The ultimate outcome is two-fold: 1) EIN provided hydrogen stakeholders with appropriate information to capture a full range of monetary benefits that are currently available to them through the LCFS program, and 2) EIN provided an assessment of the current and future impacts of the renewable hydrogen requirements and explored alternative options to better incentivize renewable hydrogen investments.

Ultimately, further research into renewable hydrogen pathways, economics and incentive structures is necessary in order to establish and validate viable actions that stakeholders can take to ensure that the FCEV community maximizes reductions in carbon emissions and other pollutants with adverse impacts to public well-being. This work is of critical importance in the developmental phase of support infrastructure.

Phase II Costs

The table below represents the cost-share EIN used to perform Phase II. This funding matches what EIN planned at the onset of the project phase.

Phase II Cost-Share (Actual)	
SCAQMD	$80K
CaFCP	$20K
Toyota	$25K
Total	**$125K**

[3] http://www.einow.org/images/stories/factsheets/ein_creditinghydrogen.pdf

SCAQMD Contract #14622 **May 2015**

CSULB Student Educational Project to Demonstrate Graphene Fuel Cell Catalysts

Contractor

California State University, Long Beach (CSULB) Foundation, Center for Energy and Environmental Research and Services (CEERS)

Cosponsors

SCAQMD

Project Officer

Alfonso Baez

Background

Proton exchange membrane fuel cells (PEMFC) convert hydrogen to electricity efficiently, with water as their main waste product. Their small size and low operating temperature (~70-85^{o}C) make PEMFCs ideal for automotive applications, replacing the engine. They could also be used in larger stationary or locomotive applications. Two materials that are challenges for this technology to realize commercialization are: platinum (Pt) catalysts and Nafion PEMs. Both materials are high cost and have durability issues. In addition, the performance of the Pt catalyst needs to be improved to realize greater conversion efficiency in PEMFCs. The major motivation for this study was to find dramatically less expensive cathode catalysts for PEMFC than pure Pt, while maintaining or improving the high performance for the Oxygen Reduction Reaction (ORR) exhibited by Pt.

Previous studies have examined the performance of the ORR by replacing Pt with a non-Pt catalyst. An example would be to replace Pt by palladium (Pd) alloys. The studies found that the Pd alloy catalysts performed better than pure Pd. However, their performances are still worse than Pt. Another strategy is to replace Pt with a Pt alloy that contains nickel (Ni) or cobalt (Co). Pt3Ni and Pt3Co are found to have improved ORR performance over pure Pt while reducing the Pt loading by 25%. However, these catalysts suffer from durability issues, as it was found that the Co or Ni leach into the fuel cell electrolyte during operation.

For PEMFC to become commercially available, it would need an ideal ORR catalyst with improved performance, lower cost, and improved durability. The iodine-edged graphene catalysts can potentially fill this role as the catalysts were found to have 33% higher current than Pt catalysts. These catalysts maintained 85.6–87.4% of their initial current after 10,000 cycles compared to 62.5% for Pt electrodes when tested in an alkaline environment. Thus, further research to test these catalysts in a complete fuel cell system is much needed to demonstrate improved performance and durability.

Project Objective

The objective of the project was to investigate the performance of iodine-edged graphene catalysts for PEMFC under operating fuel cell conditions and compare the results with the performances of the traditional catalysts.

The followings tasks were followed to meet the objectives of the investigation. Each task was broken up into one of three categories: Catalyst Synthesis, membrane-electrode assembly (MEA), and Simulation.

Task 1 - Synthesis of iodine-edged graphene catalysts (Catalyst Synthesis) and Perform ORR binding energy calculation of iodine-edged graphene catalysts.
Task 2 - Construct individual MEA with Pt and with iodine-edged graphene catalysts.
Task 3 - Perform ORR barrier calculation of iodine-edged graphene catalysts.
Task 4 - Assemble and test complete fuel cells with both Pt and iodine-edged graphene catalysts.
Task 5 - Propose atomistic model on the chemical advantage of iodine-edged graphene catalysts.
Task 6 - Use the insights gleaned from the atomistic model to improve experimental results.
Task 7 - Data assessments. Submission of the draft final report.

Technology Description

All experiments were performed in the chemical engineering laboratory at CSULB. Iodine-edged graphene catalysts were synthesized from graphene oxide and iodine purchased commercially. They were incorporated into a Membrane Electrode Assembly (MEA) consisting of catalyst, carbon and Nafion. The MEA was placed into a fuel cell stack assembly where H2 and O2 gas reacted

electrochemically. The current and voltage were recorded to determine the efficiency. The experiments were also performed for a standard PEMFC with Pt catalysts. This part of the investigation provided the baseline data for comparing the new catalysts to the existing commercial catalysts.

Density functional theory (DFT) calculations were performed to calculate the binding energy of ORR species (O, O2, OOH, H2O, OH) on iodine-edged graphene catalysts. In addition, the barriers of the ORR were calculated to compare the theoretical performance of these catalysts versus Pt, which was previously calculated. This provided an atomistic understanding on how and in what environment the iodine-edged graphene catalysts perform better than Pt.

Status

The project has been completed and the final report was submitted in May 2013. There was one final batch of catalyst still untested.

Results

Commercially available Pt and graphene catalysts from Fuel Cell Etc were tested to obtain the baseline data. CSULB group also manufactured a Pt and six graphene membrane electrode assemblies (MEA), the latter with different compositions, to compare outputs with the baseline data. All MEAs were tested under three different conditions; open circuit, 1 mA and 10 mA loadings. Results show a maximum of 0.35 volts for the CSULB MEA as compared to a slightly higher than 0.7 volt for the commercially available MEA.

X-ray diffraction was used to analyze the synthesis. The sample consists of 100% graphite initially, and should not have contained any graphite after the synthesis. The first sample contained a large graphite peak. The performance was poor. Afterwards, the ball-mill time was increased to 14 days, which made the sample better. Still, the performance was not as good as the collaborator's. Finally, for sample #3, a new ball mill with RPM of 1500 was purchased. This was able to remove all graphite peaks.

The binding energy of various ORR intermediates on graphene was calculated. In addition to calculating the binding energy of these species on bare graphene, the possibility of oxygen as a species underneath to see how it will affect the binding energy was investigated. Table 1 provides the binding energies.

Binding Energy (eV)	O	OH	OOH	OO	H_2O
Oxidized Graphene	2.02	2.25	0.22	unstable	unstable
Graphene	0.86	0.49	unstable	unstable	unstable
Pt	3.68	2.28	1.52	1.28	0.22

Table 1: Calculated binding energy of graphene and graphene-O. Comparison is made of binding energy of previously calculated results for Pt.

The data shows that the binding energy is greatly facilitated by O species on the underside. This theory explains a couple of phenomenon found in graphene fuel cells:

1. It explains why graphene is needed as a catalyst rather than normal graphite. Because graphite only allows binding on one side, the other side is not exposed to oxygen, which will enhance binding and lead to catalytic activity.

2. Graphene type fuel cells typically work better in basic conditions vs. acidic. This explains why a base environment is advantageous, because base will not dissolve oxides, which seems to facilitate the fuel cell reaction.

The graphene fuel catalyst results showed a lower voltage than Pt. This was explained by the acidic environment of the PEMFC tested, which are incompatible with graphene catalysts.

Benefits

Compared to platinum, graphene and iodine are both abundant materials. If the potential of this catalyst could be realized in a complete fuel cell system, the cost of fuel cells would decrease significantly, resulting in improved commercialization of fuel cell technology and reduction in ambient air pollution.

Project Costs

The project was completed with funding from the SCAQMD for $28,000 and cost-share contributions in the form of space and laboratory equipment and additional person-hours.

Commercialization and Applications

Further steps are required to refine the manufacturing process and improve the performance of the graphene and iodine catalyst, before commercialization. Strategies need to be developed at the atomic level to dope the graphene, so that the intermediate OOH species can be stable in an acidic environment, where there are no adsorbed oxides.

SCAQMD Contract #15020 **October 2015**

Develop Sampling and Testing Protocols for Analyzing Impurities in Hydrogen

Contractor
University of California, Irvine

Cosponsor
SCAQMD

Project Officers
Raul Dominguez, Rudy Eden & Lisa Mirisola

Background

Hydrogen is an alternative transportation fuel that is expected to play a role in reducing both fossil fuel usage and air pollutants including greenhouse gases (GHGs). The SCAQMD is committed to the promotion and facilitation of alternative fuel usage including hydrogen in support of its mission to attain healthy air in the Los Angeles basin. Use of hydrogen as a motor vehicle fuel requires the ability to verify that the fuel can satisfy SAE J2719 and the California Code of Regulations (CCR), Title 4, Division 9, Chapter 6, Article 8, Sections 4180-4181 – Hydrogen fuel quality requirements.

Project Objective

SCAQMD sought to demonstrate the ability of measuring contaminants in hydrogen to the specifications defined in SAE J2719 and the CCR by identifying analytic instrumentations and demonstrating their ability to meet hydrogen vehicle fuel quality measurement requirements. Work under this contract was to identify and develop several methods to determine and quantify "trace contaminants" present in hydrogen intended as an alternative transportation fuel for motor vehicles. The challenge is to detect contaminants at the concentrations specified in the SAE J2719 and the CCR. The three primary targeted tasks under the contract were: 1) to evaluate existing analytical methodologies and instrumentation available at the University of California Irvine (UCI) for suitability by analyzing some of the "trace contaminants" (H_2O, CO, CO_2, THC, TH, NH_3, HCOOH, and TS) listed in SAE J2917 and the CCR for hydrogen automotive fuel (proof of concept); 2) to investigate alternative technologies and instrumentation to perform analysis of trace contaminants in hydrogen fuel, including cavity ring-down spectroscopy (CRDS), proton transfer reaction-mass spectrometry (PTR-MS) and/or other technologies; and 3) to develop and submit recommendations on instrumentation needed to establish a hydrogen fuel test center and develop standard operating procedures (SOPs) for sample collection and analytical methods.

Technology Description

Formaldehyde was collected with a DNPH cartridge and analyzed with high-performance liquid chromatography (HPLC). Extensive chamber study (at UCI) and a field study (at CSULA) demonstrated the success in determining formaldehyde to the required concentration stipulated in SAE J2719 and the CCR. Multiple sampling times and flow rates were tested. The two most ideal sampling times and flow rates found were 120 minutes with a flow of 1 L/min hydrogen or 80 minutes with a flow of 1.5 L/min hydrogen. Although formaldehyde was not found in the H_2 from the CSULA fueling station, chamber studies suggest that this methodology satisfies the SAE J2719 and CCR requirements.

Proof of concept was established by collecting hydrogen on August 29 and September 3, 2014, at the Newport Shell station and analyzing trace contaminants with existing analytical methodologies and instrumentation available at UCI. Over the two days, multiple samples were collected using the hydrogen quality sampling adapter (HQSA), which was interfaced with step-down regulator to collect smaller canisters. Also, an ammonia (NH_3) cartridge developed by Professor Barbara Finlayson-Pitt's group was used to collect and determine the NH_3 content in the same H_2 fuel. The NH_3 trapped in the cartridge was analyzed with ion-chromatography (IC). Professor Donald R. Blake's non-methane hydrocarbon (NMHC) system [consisting of five columns/detectors (two FIDs - Flame Ionization Detectors, two ECDs - Electron Capture Detectors, and a MS - Mass Spectrometer) in three-gas chromatographs (GCs)] was used to determine

total hydrocarbons (THC) and halogenated hydrocarbons (TH).

Results

On average, H_2 from the Newport station consisted of approximately 407 part-per-trillion (ppt) of TH (particularly perchloroethylene), 539 ppt of THC (particularly toluene) and 3 ppb of NH_3. Also, during the sampling procedure, high water content was observed. However, water could not be quantified with instrumentations used at the time. The analysis demonstrated that existing analytical methodologies and instrumentations available at UCI were capable of measuring some of the target analytes required by SAE J2719 and the CCR.

Demonstration of the proof of concept initiated the second task, which is to investigate the suitability in using other instrumentations and technologies to determine other contaminants in hydrogen (such as carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), formaldehyde and water). PTR–MS and fourier transform infrared spectroscopy (FTIR) were two alternative technologies investigated under this phase of the contract. As an alternative technology, DNPH cartridge sample collection followed by HPLC analysis was used to analyze formaldehyde in H_2. Commercially available CRDS was another technology proposed for investigation; however, a functional CRDS was unavailable, therefore, analysis for total sulfur (TS) using CRDS could not be performed.

PTR-MS is one of the alternative technologies used as a real-time VOC analyzer. The results indicated that PTR-MS, without modification, cannot be used to analyze VOCs under high H_2 content via hydrogen fuel. A pre-concentrator, such as a Markes International or Entech thermal desorber, could be used to pre-concentrate fuel contaminants (e.g. VOCs) and remove excess H_2 prior to PTR-MS analysis. On the other hand, FTIR used as a competing alternative technology successfully determined the CO, CO_2, and CH_4 concentration and satisfied SAE 2719 and CCR requirements. Detailed analysis and validation using FTIR from MKS Instruments were conducted under this contract.

The following table summarizes measurement objectives as defined in SAE 2719 compared to actual measurements under this contract.

Constituent	Limits	J2719 Minimum Analytical Detection Limit	Contract #15020 Determined Detection Limit
Water	5	0.5	0.12
Total hydrocarbons (C_1 basis)	2	0.1	0.1
Carbon dioxide	2	0.1	0.1
Carbon monoxide	0.2	0.2	0.01
Formaldehyde	0.01	0.01	0.01
Ammonia	0.1	0.1	0.02

Benefits

The SCAQMD or other entities can perform analysis of "trace contaminants" in H_2 fuel to satisfy the criteria in SAE J2719 or the CCR.

Project Costs

SCAQMD provided full funding totaling $114,500 from the Clean Fuels Fund for this contract.

Commercialization and Applications

Contract outputs included a list of instrumentations and associated vendors needed to satisfy the requirements listed in SAE J2719 and the CCR. The deliverables include standard operating procedures (SOPs) and Operation Assistance Guides for the HQSA, FTIR, NMHC system, DNPH cartridge and NH_3 cartridge usage. The final report also recommends further investigations to determine the feasibility of analyzing other contaminants listed in SAE J2719 such as helium, nitrogen and particulate matter in motor vehicle grade hydrogen.

SCAQMD Contract #15666 **December 2015**

Participate in California Fuel Cell Partnership for CY 2015 and Provide Support for Regional Coordinator

Contractor

Bevilacqua-Knight, Inc.

Cosponsors

7 automakers; 6 government agencies;
1 technology provider;
8 associate members; and
14 affiliate 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 Bevilacqua-Knight, Inc. (BKi) for their portion of CaFCP administration. SCAQMD joined the CaFCP in April 2000, and the CaFCP currently includes 36 organizations interested in demonstrating fuel cell vehicle and fueling infrastructure technology.

Project Objectives

Several key goals for 2015:

- Convene CaFCP members and stakeholders in a common forum to discuss challenges and opportunities, exchange experiences and knowledge, and advance group sharing and progress. Build and expand trust among members via open communication. Maintain and enable the organization to achieve its mission and goals.
- Collaborate to identify and address emerging challenges and translate into comprehensive and durable solutions. Retain the flexibility to address issues quickly as they arise, in the interest of advancing all members and industry.
- Communicate, educate, inform and promote H2 & FCEVs benefits and opportunities to key outside stakeholders and general public for increased and continued support. Become readily recognized as the face of the industry for trustworthy information and assistance.

Status

The members of the CaFCP intend to continue their cooperative demonstration efforts and have set goals through 2016, subject to a budget approved annually. This final report covers the SCAQMD Contract #15666 for 2015 membership. This contract was completed on schedule.

Representatives from BAE Systems and Ballard talk with staff of Orange County Transportation Authority and other transit agencies during CaFCP-organized tour of four fuel cell electric buses under construction at El Dorado facility in Riverside.

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 Daimler's B Class F-CELL, GM's Chevy Fuel Cell Vehicle, Honda's Clarity FCX and FCV, Hyundai's Tucson, Nissan's XTrail, Toyota's Mirai and FCHV-*adv* and VW/Audi's Golf Sportwagen HyMotion and A7 h-tron. The fuel cell transit

buses include 12 placed at AC Transit (Van Hool buses with UTC fuel cells) and 4 placed at Sunline Transit (1 Ballard/New Flyer and 3 Ballard/BAE/ElDorado).

Results

Specific accomplishments include:

- Automotive members placed over 500 fuel cell passenger vehicles on California roads from 1999 through 2015, including the first retail customers starting in 2005;
- Transit agency members have demonstrated 28 fuel cell buses since 1999, with 19 currently in operation (see technology description);
- There are six retail and six other public hydrogen fueling stations in operation in California. There are also 40 in development in California;
- CaFCP staff and members continue to train local fire departments and work with emergency response organizations to coordinate with state and national efforts;
- CaFCP, the Governor's Office of Business and Economic Development and the California Energy Commission, continue briefing city staff across the state of California to optimize station permitting.
- CaFCP, GO-BIZ, CEC and others, hosted briefings and permitting workshops across the state for local government staff and elected officials.

Benefits

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

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

Project Costs

Auto members provide vehicles, 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 member makes an annual contribution of approximately $85,000 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 2015 was $134,800.

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 can play 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.

From 2013 to 2016, CaFCP's goals relate to Preparing for Market Launch through coordinated individual and collective effort. During this fourth phase, CaFCP members, individually or in groups, will focus on important goals.

- Prepare for larger-scale manufacturing, which encompasses cost reduction, supply chain and production.
- Work on the customer channel, including identifying and training dealers and service technicians.
- 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 RD&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 zero-emission electric drive.

SCAQMD Contract #13168 **December 2015**

CRADA: Develop, Integrate and Demonstrate Heavy-Duty Natural Gas Engines and Vehicles

Contractor

National Renewable Energy Laboratory

Cosponsors

SCAQMD
CEC
U.S. DOE
SoCalGas

Project Officer

Adewale Oshinuga

Background

On-road natural gas engines are now being used on a limited basis as an alternative to diesel engines in transit, refuse, and goods movement applications. While the number of these engines has grown, there is still a need to develop natural gas engines in the 11- to 14-liter range to fill the wide array of fleet applications currently served by diesel engines. As such, on March 4, 2011, the Board awarded a contract to the DOE's National Renewable Energy Laboratory to administer the development, integration, and demonstration of heavy-duty natural gas engines and vehicles.

Project Objective

The primary objectives of this project included the following:

- Develop a new, high-efficiency, high-performance, high-versatility, low-emissions, heavy-duty 11.9 liter natural gas engine and three-way catalyst after-treatment;
- Certify the new engine at or below EPA / CARB 2010 on-highway emission standards;
- Achieve fuel efficiency within 5-15% of comparable EPA/CARB 2010 on-highway certified diesel engines; and
- Achieve OEM availability in a range of vehicles commonly used by fleet operators in the North American regional haul and vocational Class 8 truck and tractor market.

Technology Description

The engine technology is a spark-ignited stoichiometric natural gas engines with cooled exhaust gas circulation (EGR) and a three-way catalyst (TWC) after-treatment system. The cooled EGR systems reduce engine NOx emissions by mixing incoming fresh air with a measured quantity of cooled exhaust gas to lower peak combustion temperature. The TWC converts NOx, CO, and HC to nitrogen, carbon dioxide, and water in the presence of a catalyst.

Status

Cummins Westport, Inc., (CWI), working as a subcontractor to NREL, successfully completed the project and developed a 11.9-liter ISX12 G engine as a spark-ignited, stoichiometric, cooled exhaust gas recirculation (SI-EGR), natural gas engine certified to the EPA/CARB heavy-duty on-highway 2013 emission standards. CWI commercially launched the ISX12 G engine with ratings up to 350 HP and 1450 lb-ft beginning in mid-April 2013, and with ratings up to 400 HP and 1450 lb-ft in August 2013. This engines will be used in refuse, transit and Class 8 heavy-duty truck applications.

ISX12 G Engine

Results

The ISX12 G engine meets EPA greenhouse gas legislated requirements and Engine Manufacturer's Diagnostics (EMD+) certification. The ISX12 G engine met final certification (including Deterioration Factor) at:

- 0.15 g/bhp-hr NOx for both EPA and CARB
- 0.03 g/bhp-hr NMHC for both EPA and CARB
- 8.4 g/bhp-hr (EPA) and 8.7g/bhp-hr (CARB) CO
- Less than 0.003 g/bhp-hr PM

Benefits

The ISX12 G engine is certified to the EPA/CARB heavy-duty on-highway 2013 emission standards and also meets EPA greenhouse gas legislated requirements and Engine Manufacturer's Diagnostics (EMD+) certification. It is now being used as alternative to diesel engines in various applications which require high-horsepower engines.

Project Costs

This project was originally part of a natural gas engine development and demonstration program for three projects. The program cost was estimated to be $15,245,000, of which SCAQMD provided $2,555,000 in addition to $500,000 in cofunding from SoCalGas. The U.S. DOE, CEC, and private partners provided the remaining $12,190,000 in direct funding and in-kind contributions. The other two projects were discontinued because one subcontractor went out of business, and the other lacked financial support. Since the program was not completed, the cost of this project was $3,607,651, of which SCAQMD provided $797,629.

Commercialization and Applications

The ISX12 G engine is now available as a factory-installed option in a number of Class 8 truck and tractor models from different OEMs including Autocar, Freightliner, Kenworth, Mack, Peterbilt, and Volvo. This engine will be used in refuse, transit and Class 8 heavy-duty truck applications.

SCAQMD Contract #07243 **December 2015**

Purchase and Install New Public Access L/CNG Fueling Station

Contractor
City of Commerce

Cosponsors
Federal Transit Administration
MSRC/AB 2766 Discretionary Program
Caltrans
SCAQMD
City of Commerce

Project Officer
Larry Watkins/Phil Barroca

Background
To comply with SCAQMD's fleet rules, the City of Commerce began to transition its transit fleet to CNG. In 2003, the City of Commerce began planning for the installation of a new L/CNG facility. The new station would provide convenient, local refueling for the City's 11 CNG transit buses, which since 2009 had been fueling at a CNG station in Bellflower, as well as accommodate City plans to expand its natural gas fleet. It would also allow for refueling by other local alternative fuel fleets including private waste sanitation companies, taxicabs and limos and could be a convenient refueling location for Port drayage trucks. The site chosen was the Los Angeles County Sanitation District's Waste-to-Energy facility located at 5940 Shelia Street in the City of Commerce. The site is near the intersection of Washington Boulevard and Interstate 5.

Project Objective
The objective of this project was to design, construct and commission a new publicly accessible L/CNG refueling station that would serve the needs of the City of Commerce and other private and municipal fleet users. The station would also help achieve the goal of reducing air pollution in and around the Commerce community as well as continue development of the Interstate Clean Transportation Corridor (ICTC), which fosters alternative fuel vehicle infrastructure development for heavy-duty vehicles throughout California and into Nevada, Utah and Arizona.

Technology Description
The L/CNG fueling station consists of a 15,000 LNG storage vessel mounted on a containment area designed to accommodate a second vessel in the future. Fuel is produced in Boron, CA, with LNG trailers filling the storage vessel by means of a dedicated LNG transfer pump. The LNG tank feeds LNG to a single submerged-type multi-purpose LNG pump that delivers LNG to both an LNG dispenser and to a high pressure reciprocating L/CNG pump. The LNG system includes an LNG conditioner (saturation coil) designed to maintain the saturation pressure between 65 and 125 psig within the storage vessel. The station includes one LNG dispenser located adjacent to the containment area. CNG is produced by pumping the LNG through a high-pressure vaporizer to produce CNG, which is odorized and stored in a bank of high-pressure storage containers (high, mid and low). The CNG storage supplies CNG through a CNG priority panel to two dual-hose CNG dispensers–one transit type and one regular type–located on a new CNG dispenser island. A Programmable Logic Control system is integrated to control all LNG/LCNG functions. The station also includes a card reader for credit card purchases.

Status
After a three-year process, the station was commissioned in August 2010.

Figure 1: New L/CNG Fueling Station

In November 2007 the City of Commerce was granted a Categorical Exclusion by FTA to construct its station and an RFP to solicit design-build proposals was released on September 2, 2008. The City Council awarded the contract to General Physics and a ground-breaking ceremony was held on April 29, 2010. Construction included site preparation, civil work, demolition and/or relocation of existing facility equipment, and the new station included all equipment, controls, containment areas, piping, electrical connections, paving, fencing, lighting, signage, and landscaping. The start of construction was delayed because the soil at the existing site was not dense enough to support the weight of the L/CNG station so the contractor had to re-compact the soil at the site before construction began. Further delays were caused by a lengthy permit review process and inclement weather. The station opened 24/7 to the general public in September 2010, with a formal ribbon-cutting ceremony conducted on August 5, 2010. The SCAQMD contract ended December 31, 2015, after five years of reporting.

Results

When the City introduced its new CNG transit fleet in early 2009, it resulted in a 90 percent reduction in emissions over the old diesel buses. The new L/CNG station has now allowed the City to fuel transit buses within one mile of its Transportation Department facility, realizing a reduction of 90 cents per gallon in costs or an estimated annual savings in fuel costs of $80,000.

Figure 2: City of Commerce transit bus fueling at the new L/CNG station

Annual throughput was estimated at 347,000 gallons of LNG by the end of the third full year of operation. This table reflects actual throughput during the five years of reporting required by the SCAQMD.

Year	City	Third Party	Total LNG Sales in GGE
2011	92,627	115,915	208,542
2012	98,707	395,539	494,246
2013	115,420	804,707	920,127
2014	125,064	999,830	1,124,894
2015	131,056	846,952	978,008

Benefits

In addition to enhancing the regions clean fuel infrastructure, the new L/CNG station is one more step towards reducing dependence on imported oil, with 98 percent of the LNG fuel used at the station coming from domestic fuel sources.

Project Costs

SCAQMD's cost-share was eight percent of the total.

FUNDING SOURCE	AMOUNT
Federal Transit Administration	$2,198,997
Caltrans	$273,577
MSRC/AB 2766 Discretionary Fund	$350,000
SCAQMD-Clean Fuels	$250,000
City of Commerce, Transportation Development Act, Article 4	$110,674
City of Commerce, Measure R Clean Fuels & Miscellaneous	$38,739
City of Commerce, Capital Improvement Program	$68,602
TOTAL	**$3,290,589**

Commercialization and Applications

The new L/CNG fueling station is similar to other stations in Southern California; however, its location specifically helps foster growth in the regional heavy-duty natural gas vehicle fleet. In fact, the 1,000 new LNG trucks deployed in 2011 nearby the Ports of Los Angeles and Long Beach will now have a convenient fueling location near the BNSF and Union Pacific railyards in Commerce.

SCAQMD Contract #07309 **June 2015**

Repower One Off-Road Construction Vehicle

Contractor
Post Company Grading

Cosponsor
SCAQMD
Post Company Grading

Project Officer
Vasken Yardemian

Background
Based on the California Air Resources Board (CARB) OFFROAD 2006 emission model, there were approximately 68,600 diesel-powered off-road construction vehicles in the South Coast Air Basin in 2006, which together produced approximately 120 tons of NOx and 7.5 tons of PM emissions per day. In order to reduce diesel emissions of NOx and PM, the SCAQMD has provided incentive funding to operators of diesel-powered off-road construction vehicles to go beyond regulatory requirements to repower, or replace their engines with newer and cleaner ones.

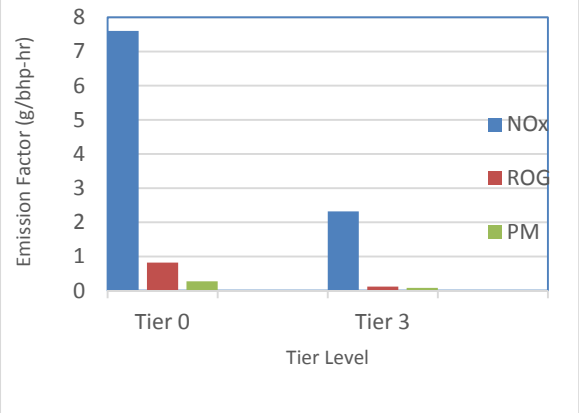
On April 6, 2007, the SCAQMD Board awarded a contract to Post Company Grading to repower one Tier 0 diesel-powered dozer (off-road construction vehicle) with a new Tier 3 diesel engine in an amount not to exceed $92,244 from the Clean Fuels Fund. This project was one of several funded projects as part of a required match for the Carl Moyer Air Quality Standards Attainment Program (Carl Moyer Program) and was administered according to the 2005 Carl Moyer Program Guidelines.

Project Objective
The purpose of this project is to reduce emissions from construction equipment through the repower of one diesel engine dozer to meet the CARB Tier 3 emission standards of 2.32 g/bhp-hr of NOx, 0.12 g/bhp-hr of ROG and 0.088 g/bhp-hr of PM10.

Technology Description
A repower is the replacement of the existing engine with a new lower-emission CARB-certified engine. The repower consisted of removing the existing engine and accessory components and installing a new engine and associated accessory components. The repower was performed by Quinn CAT, an independent Caterpillar dealership using Caterpillar factory engine and accessories along with specially fabricated components (brackets, wire harnesses, hoses, etc.) needed to fit the new engine into the existing vehicle.

Repower is typically more cost effective in reducing emissions than replacing a vehicle, due to the higher cost of a new vehicle compared to just a new engine. The emission reduction from Tier 0 to Tier 3 is 70% for NOx, 85% for ROG (reactive organic gases) and 68% for PM. The following chart illustrates the difference in emissions between Tier 0 and Tier 3 engine emission factors.

Figure 1: Carl Moyer Program Emission Factors



Status
The project was scheduled to be completed by June 2008. However due to the economic downturn of the construction industry and the

non-availability of Tier 3 engines, SCAQMD agreed on an extension of the contract till November 2008. The dozer was placed in service thereafter. The Contractor made all the operational information for the vehicle available to SCAQMD including the annual hours of operation. According to the Contractor, the vehicle performed well; however, it ran hot from time to time. No major problems to report. The project life was seven years.

Figure 2: Caterpillar D9N Dozer Repowered to Tier 3

Results

The repowered vehicle was inspected by SCAQMD to confirm that the repower was completed properly, the old engine was permanently destroyed and the repowered vehicle was fully operational.

Benefits

The emissions benefit of the repower was calculated according to the Carl Moyer Program Guidelines. The Tier 3 engine in the repowered dozer was estimated to reduce emissions by 2.24 tons per year of NOX+ROG and 0.07 tons per year of PM10 compared to the original Tier 0 engine.

Project Costs

The total actual cost of the project was $121,942. The cost of the new Tier 3 engine and parts was $95,900 and the labor cost was $26,041. SCAQMD's funding contribution was $92,244, paid to the contractor from the Clean Fuels Fund. Originally the project cost was estimated at $140,344. However, Quinn CAT, the repowering company, issued a $15,000 discount on the labor.

Commercialization and Applications

Repower technologies using Tier 3 diesel engines for off-road construction vehicles are commercially available for a variety of off-road equipment. The current emission standard is Tier 4 and repowers using Tier 4 engines are generally not technically feasible in older off-road vehicles. Preference is now being given to replacement projects using new equipment meeting Tier 4 standards.

SCAQMD Contract #07312 **June 2015**

Repower of 11 Off-Road Construction Vehicles

Contractor
Mesa Contracting Corporation

Cosponsor
SCAQMD
Mesa Contracting Corporation

Project Officer
Mark Coleman

Background
Based on the California Air Resources Board (CARB) OFFROAD 2006 emission model, there were approximately 68,600 diesel-powered off-road construction vehicles in the Basin in 2006, which together produced approximately 120 tons per day of NO_x and 7.5 tons per day of PM emissions. In order to reduce diesel emissions the SCAQMD has provided incentive funding to operators of diesel powered off-road construction vehicles to upgrade to cleaner technology.

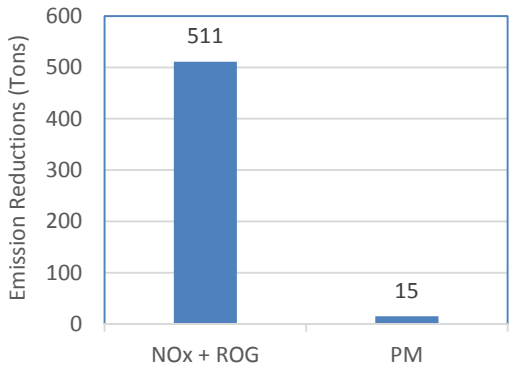
On April 6, 2007, the SCAQMD Board awarded a contract to Mesa Contracting Corporation to repower thirteen Tier 0 diesel-powered off-road construction vehicles with new Tier 3 diesel engines in an amount not to exceed $1,062,007 from the Clean Fuels Fund. This project was one of several funded as part of a required match for Carl Moyer Memorial Air Quality Standards Attainment Program (Carl Moyer Program) projects and was administered according to the 2005 Carl Moyer Program Guidelines.

Project Objective
The purpose of this contract was to reduce emissions from diesel powered off-road construction vehicles by repowering them to meet CARB Tier 3 emission standards, the most stringent at that time.

Technology Description
Repower is the replacement of the existing engine with a new lower-emission CARB-certified engine. The repower consisted of removing the existing engines and accessory components and installing new engines and accessory components. The repower was performed by an independent Caterpillar mechanic using Caterpillar factory engines and accessories, and using specially fabricated components (brackets, wire harnesses, hoses, etc.) needed to fit the new engine into the existing vehicle.

Repower is more cost effective in reducing emissions than replacing the vehicle due to the much higher cost of a new vehicle compared to the cost of a new engine. The following chart illustrates the repowered construction equipment emission reductions for the seven-year project life.

Figure 1: Emission Reductions for Repower of 11 Off-Road Vehicles



Status
Eleven scrapers of the type shown below were repowered in 2008. Beginning in 2008, construction activity was substantially reduced due to the severe economic recession. As a result, the contractor did not repower the remaining off-road construction vehicles. Unspent contract funds were returned to the Clean Fuels Program Fund for use on other projects.

Figure 2: Caterpillar 651B Scraper Repowered to Tier 3

Results

The repowered vehicles were inspected by SCAQMD to verify that the repower was completed properly, the old engines were destroyed, and the repowered equipment was fully operational.

Benefits

The emission benefits of the repowers were calculated according to the Carl Moyer Program Guidelines. The Tier 3 engines were estimated to reduce emissions by 73 tons/year NOx+ROG and 2.2 tons/year PM compared to the original Tier 0 engines.

Project Costs

A total of $898,622 from the Clean Fuels Program Fund was paid to the contractor. In addition, the contractor paid another $320,654 for a total project cost of $1,219,276. A total of $163,385 was returned to the Clean Fuels Program Fund.

Commercialization and Applications

Repower technologies using Tier 3 diesel engines for off-road construction vehicles are commercially available for a variety of off-road equipment. The current emission standard is Tier 4 and repowers using Tier 4 engines are generally not technically feasible in older off-road vehicles. Preference is now being given to replacement projects using new equipment meeting Tier 4 standards.

SCAQMD Contract #07236 **December 2015**

Collaborative Lubricating Oil Study on Emissions (CLOSE)

Contractor
National Renewable Energy Laboratory (NREL)

Cosponsors
Southwest Research Institute (SWRI)
Desert Research Institute (DRI)

Project Officer
Joseph Impullitti

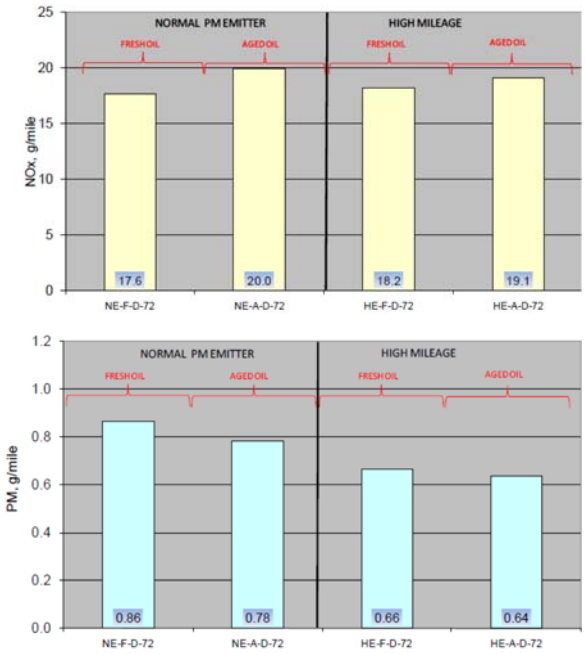
Background
According to official government inventories, mobile sources currently account for a third of the directly emitted PM2.5 emissions in California's South Coast Air Basin (SoCAB), with gasoline-powered vehicles accounting for less than 10% (CARB, 2008). However, model predictions have shown that gasoline-powered vehicles may account for 60% of the total predicted secondary organic aerosols (SOA) in the SoCAB during summer (Kleeman et al., 2007).

Project Objective
The objective of this project was to conduct chemical and physical characterizations of particulate matter (PM) emissions from a limited number of vehicles fueled respectively with gasoline, E10, diesel, biodiesel, and natural gas while operating on fresh and used crankcase lubricants in an effort to investigate methodologies to indicate how fuels and crankcase lubricants contribute to the formation of PM and semi-volatile organic compound (SVOC) emissions in vehicle exhaust.

Technology Description
This project was initiated to characterize particulate matter (PM) emissions from four vehicle types operating on multiple fuels and lubricants at two test temperatures. The four vehicle types studied were: light-duty gasoline passenger cars, medium-duty diesel trucks, heavy-duty natural gas fueled transit buses, and heavy-duty diesel transit buses. Two vehicles of each vehicle type were selected and studied: one normal PM emitting vehicle and one high PM emitting (or high mileage) vehicle. PM characterizations were carried out to investigate whether the relative contribution of lubricant to particulate could be estimated, and whether the lubricant contribution to PM changed with different fuels and lubricant compositions.

Status
The CLOSE project was a pilot program to investigate methodologies to indicate how fuels and crankcase lubricants contribute to the formation of particulate matter (PM) and semi-volatile organic compounds (SVOC) in vehicle exhaust. It was conducted with a very limited number of vehicles, some of which did not have the latest engine and emission system technology, and no vehicles in this study were equipped with particle traps. The results of this study are not representative of the whole fleet of on-road vehicles. Long term lubricant effects on engine and after-treatment were not investigated in this study.

Results
Average regulated gaseous emissions, PM emissions, and fuel consumption rates while operating the vehicles with fresh and aged oil are included. Standard deviations and co-variances of the replicate tests are also provided (each replicate being comprised of one cold start and one hot start heavy-duty driving cycle [HDDC] test). All heavy-duty emission tests were conducted at a nominal 72ºF ambient temperature. Repeatability of the emissions from the replicate tests was good. As shown in Fig. 1, hydrocarbon rates measured from the normal emitter (NE) bus on aged oil showed the greatest variability between the two replicate tests with a covariance of 15 percent. NOx emissions from the NE also exhibited higher variability with a covariance of 11 percent on fresh oil. In addition, hydrocarbon emissions from the high mileage (HM) bus with high blow-by on aged oil showed a covariance of 11 percent, but all other emission rates exhibited lower variability with co-variances below 10 percent.



NOx and PM Comparative of Fresh and Aged Oil

For the normally-operating light-duty gasoline and medium-duty diesel vehicles and for both heavy-duty natural gas vehicles, fresh oil produced more particles than aged oil. The opposite trend occurred with the light- and medium-duty high PM emitters. This effect was not readily apparent with the heavy-duty diesel vehicles. One explanation could be that, since the lubricant represented a much smaller fraction of the total PM (around 20 percent) in the HD diesel vehicles, the effect was lost in the precision of the testing methodology.

In many cases, emitted PM was incompletely accounted for with chemical analyses. It is possible that some fraction of unburned and/or partially combusted fuel and oil, or some polar fraction of PM, was not measured with the analytical techniques used in this program.

Follow-up studies should assess the methods of PM allocations used in this study on vehicles representing the diverse spectrum between normal emitters and high emitters, and should estimate the precision of the allocations obtained by running multiple analyses. Vehicles should be tested with fuels without hopanes and steranes in order to help clarify the potential confounding (or lack thereof) when markers are parented by both fuel and lubricant. Studies should be conducted to understand the relative frequency of various types and intensities of 'high emitters' to facilitate modeling of the on-road vehicle fleet.

Future Work

Future work could consider testing emissions from diesel vehicles equipped with normally-functioning particle filters to determine if this type of after-treatment system produces similar results. Also, it would be informative to utilize the latest engine and emissions system hardware for all the vehicles to determine if the considerable efforts by regulators and OEMs have impacted PM levels. Noting that aged lubricants sometimes produce less PM than fresh oil, it would be interesting to investigate the effects of base oil volatility and type (i.e., mineral-based versus synthetic) on PM and SVOC formation.

Project Costs

The total cost of the project was $446,887. The table below shows the breakdown of the funding for the project:

Funding Source	Amount
SCAQMD	$100,000
CARB	$100,000
NREL	$246,887
Total:	$446,887

Commercialization and Applications

The U.S. Environmental Protection Agency (EPA) revised the National Ambient Air Quality Standards (NAAQS) for PM10 and PM2.5 in October 2006, revoking the annual PM10 standard and lowering the 24-hour PM2.5 standard to 35 µg/m3. The existing annual 24-hour standards for PM10 and PM2.5 (150 µg/m3 and 15 µg/m3, respectively) were retained. Control plans for the 2006 standards are to be submitted to EPA in the 2012-13 timeframe for areas that are in nonattainment. In preparing these plans, State and local agencies are using emissions models and chemical transport models to identify and evaluate potential emission reduction measures.

To supplement current knowledge of particulate emissions from mobile sources, and to investigate methods to identify the sources of compounds which make up particulate, the CLOSE project was undertaken with support from Federal, State, and local government agencies and industry.

SCAQMD Contract #09303 **January 2015**

Install an Approximate 40kW (AAC) Crystalline Silicon System at SCAQMD Headquarters

Contractor
PermaCity Solar

Cosponsor
SCAQMD

Project Officer
Patricia Kwon

Background

On October 3, 2008, the Board approved the execution of contracts to install two new photovoltaic (PV) systems at the SCAQMD facility in Diamond Bar, CA. The SCAQMD currently owns and operates two solar PV installations, an 80 kW (AC) system on the main building and a 20 kW solar carport.

Project Objectives

The objective of this project was to compare the performance of thin film and crystalline silicon PV modules, as well as add solar capacity for the facility. The project demonstrated two different PV technologies on the roof above the conference center. SCAQMD tested the performance and reliability of the two systems under similar light conditions. This contract report is for the PermaCity contract effort.

Technology Description

For the PermaCity crystalline silicon system, 144 Schott ASE-300DGF/50-310 (310 watt) modules and an SMA America ST 42 (277 volt) inverter (96% efficiency) were installed for an overall system output of 44.64 kW DC. This system utilized multi-crystalline photovoltaic modules, as compared to Solar Integrated Technologies' (SIT's) amorphous thin film modules, tilted at a 15 degree angle.

Status

This project was completed on June 17, 2009. During the project, there were some delays in the delivery of equipment. This issue was solved by working as efficiently as possible to keep the crew on schedule despite the delayed delivery. Since there were two separate systems and one rebate, a combined single line diagram was submitted to the City of Diamond Bar for permitting. The existing SCAQMD single line diagram was several years old and did not include four turbine engines so the single line diagram was updated. SIT was contracted to re-roof underneath the modules, delaying the project by two days. Southern California Edison mandated an unanticipated $1,041 new meter charge that was split between PermaCity and SIT.

One of the inverters utilized in PermaCity's Sunny Tower inverter malfunctioned and had to be repaired and later replaced in January 2010, as well as a broken Schott module replaced under warranty in February 2010. Data for this inverter had not been reporting since September 2009, and began reporting again in February 2010.

SCAQMD, Fat Spaniel Technologies, and PermaCity collaborated on the monitoring system and solar kiosk. In July 2010, the kiosk was upgraded to Solar Plant Vision from Fat Spaniel to separately monitor the performance of the two new solar installations as well as the first 80 kW solar installation. The kiosk experienced intermittent problems since its installation in August 2009 due to the kiosk being overloaded from too much data. Later the kiosk was replaced and upgraded by Solar City to run on a new Windows software platform and replace the 100 kW SatCon inverter gateway providing performance monitoring of the 80 kW system. Three solar PV systems totaling 160 kW were installed on the rooftop of SCAQMD's Diamond Bar headquarters building in May 2006

(80 kW), July 2009 (40 kW) and December 2009 (40 kW). The performance and production statistics of the three systems were monitored and displayed on an interactive touch-screen kiosk in the main lobby ground-level entrance.

Results

Over its lifetime, the PermaCity crystalline silicon solar installation will produce 2,764,320 kilowatt hours of electricity, preventing release of 3,427,764 pounds of C02 to be released into the air, 1,106 tons of coal to be burned and will save the equivalent of 442 acres of forest. Production data for both system is shown in Figure 1.

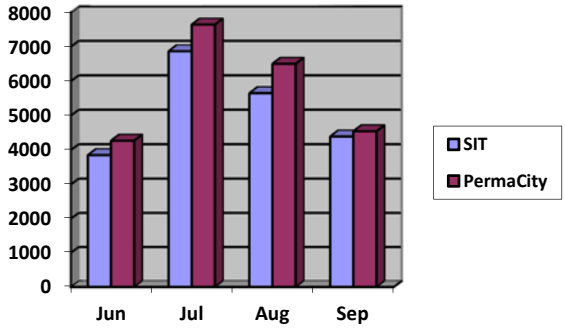


Figure 1: Solar Production

Benefits

Estimated CO2 reductions for both solar PV installations are approximately 78 tons/year using the California GREET model. The solar installation will, over the course of its lifetime, prevent release of 3,427,764 pounds of C02 to be released into the air, 1,106 tons of coal to be burned and will save the equivalent of 442 acres of forest. These numbers were reached by utilizing the GREET model, an emissions reduction calculator provided by the EPA[1].

The environmental cost of production for these modules is offset after between 1.5 - 3 years of energy production[2]. Since crystalline modules, unlike most thin film modules, do not utilize toxic cadmium in their production, there is no environmental concern regarding contamination.

Project Cost

The costs of this installation was on budget. As this was a project for SCAQMD, the entire cost of the system which totaled $387,162 was paid by SCAQMD. The entire Performance Based Incentive from Southern California Edison was received over a five-year period ending in 2015.

Commercialization and Applications

Both crystalline and thin film solar modules are already commercial products. They have both demonstrated their efficacy and applications in the renewable energy generation field. The increased demand for renewable energy has led to mass production of solar modules making them an affordable, widely available commercial product. However based on the performance of both technologies at the SCAQMD headquarters facility, it appears that multi-crystalline silicon modules performed better overall than thin film silicon modules.

[1] http://www.epa.gov/RDEE/energy-resources/calculator.html

[2] Alsema, E.A.; Wild - Scholten, M.J. de; Fthenakis, V.M. *Environmental impacts of PV electricity generation - a critical comparison of energy supply options* ECN, September 2006; 7p. Presented at the 21st European Photovoltaic Solar Energy Conference and Exhibition, Dresden, Germany, 4-8 September 2006.

SCAQMD Contract #13030 **April 2015**

Demonstrate a 300kW Molten Fuel Cell with an Exhaust-Fired Absorption Chiller

Contractor
University of California, Irvine

Cosponsors
California Energy Commission
FuelCell Energy
Southern California Gas Company
UC Irvine Medical Center
SCAQMD

Project Officer
Joseph Impullitti

Background
In California, a substantial potential exists to capture generator waste heat with an absorption chiller and provide air conditioning to meet a wide spectrum of applications that have significant cooling demands throughout the year. Such combined cooling, heat and power (CCHP) systems offer benefits of increased energy efficiency and reduced emissions of both criteria pollutants and greenhouse gases (GHGs). Needed is an ultra-clean, integrated generator/absorption chiller product to enable the California market.

Project Objective
The objectives of the project were to (1) design, deploy, commission, and operate a megawatt class high temperature fuel cell/absorption chiller (HTFC/AC) system, (2) characterize the criteria and pollutant emission reductions, (3) develop complementary HTFC/AC performance and economic models, (4) deploy a wide array of monitoring sensors to capture performance and inform the system models, (5) evaluate the performance and market value of the product in California, and (6) advance market engagement.

Technology Description
High-temperature fuel cells (HTFCs) have an unusually high electrical efficiency and high-quality exhaust heat temperature, and emit virtually zero criteria pollutants. The high quality heat can be recovered through absorption chilling (AC) for air conditioning and thereby (1) displace electricity required today for electric chillers, (2) substantially reduce the emission of criteria pollutants and GHGs, and (3) increase the reliability and reduce operating costs for the customer.

The strategy integrated a FuelCell Energy 1.4MW high temperature molten carbonate fuel cell with a BROAD 200 ton absorption chiller. A critical care facility, the UC Irvine Medical Center (UCIMC), was selected for the installation. For market engagement, a dedicated conference room was equipped to present the system design and operating principles, as well as the current and historic performance to developers and energy managers.

Status
The system and economic models were completed and utilized to design the HTFC/AC system. For the purposes of scaling, a 300kW/40Ton system was considered as well as the 1.4MW/200Ton system actually deployed. A Power Purchase Agreement was successfully negotiated between FuelCell Energy and UCIMC, and funds from the California

Figure 1: Fuel Cell

Figure 2: Absorption Chiller

Public Utilities Commission Self-Generation Incentive Program (SGIP) were successfully reserved. The system was installed under the leadership of the Otto H. Rosentreter Company, and the system is on track for commissioning in December 2015 upon completion of the interconnection agreement with Southern California Edison.

While a number of unscheduled hurdles delayed the original schedule of deployment, two were especially challenging. The first was the suspension of the SGIP that began in December 2010 and lasted more than a year before the revised SGIP process was fully implemented. The second was the interconnection agreement that was initially scheduled to be completed within months but extended to one year.

Results

The performance and economics models were applied to calculate the following projected emissions and costs associated with HTFC/AC installations.

Air Pollutant	CO_2	NO_x	SO_x
Emission Level (lb/MWh)	854	0.0087	0.00009

If the electricity and chilling generated to serve all of the commercial building loads in the Southern California Edison (SCE) service territory were generated by HTFC/AC technology, CO2 emissions would decrease by 3,272 million metric tons per year, NOx emissions would decrease by 5,470 metric tons, and SOx emissions would decrease by 171 metric tons.

Cost	FCE 1.4 MW DFC1500
Installation Cost ($/kW)	3300
Fixed Operation and Maintenance Cost ($/kW-yr)	200
Levelized Cost of Electricity (LCOE) ($/MWh)	101

The levelized cost of electricity (LCOE) goes down as the capacity factor of the installation goes up. The more the system operates, the greater the output of useful products and the lower the LCOE. The LCOE is minimized when the HTFC operates around-the-clock as a base load generator and the chiller maximizes the use of the high-quality heat. A sensitivity test, conducted to evaluate the impact of future HTFC/AC system scenarios, revealed that the fuel cell efficiency and natural gas price had the biggest effect on LCOE, with lower natural gas price and higher fuel cell efficiency resulting in a lower LCOE.

Due to the delay in installation and commissioning, no data on the unit operation are currently available. Data will be gathered from the installation at the UCIMC to both document performance and evaluate the model predictions. This activity is scheduled to commence in December, 2015.

Benefits

HTFC/AC technology has the combined benefits of (1) reducing the emissions of GHGs and criteria pollutant emissions associated with electricity generation, distribution and use, (2) enhancing the economy through technology advancement, employment, and education, (3) reducing the cost-of-electricity, and (4) increasing the reliability and power quality of electricity.

Project Costs

The total project cost was $35.1M. The project was funded by the California Energy Commission, Southern California Gas Company, the SGIP, the UCIMC, FuelCell Energy, and the SCAQMD. The contribution from the SCAQMD was $257,500.

Commercialization and Applications

An objective of the project is to enable the HTFC/AC market, a technology particularly well-suited to California. To accomplish this, a practical installation of HTFC/AC technology was completed at a highly visible location, a metering network was integrated into the design to monitor the performance of the system and components of the system, and a conference room was established to showcase the technology to the market. Market penetration is expected to lead to capital and O&M cost reductions, and facilitate corresponding GHG and criteria pollutant emissions reductions.

The knowledge and experience derived from this project has the potential to benefit the public by furthering the understanding of HTFC/AC technology. The fuel cell and absorption chiller is readily available through FuelCell Energy and BROAD U.S.A. Incorporated, respectively. This technology can be implemented at any location which has access to natural gas or biogas.

SCAQMD Contract #15347 **November 2015**

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

Contractor

West Virginia University

Cosponsors

SCAQMD
CARB

Project Officer

Adewale Oshinuga

Background

The SCAQMD funded a research program at West Virginia University (WVU) to develop a retrofit technology for stoichiometric natural gas engines capable of simultaneous reduction of NOx and ammonia emissions. In addition, the study jointly funded a program with CARB to evaluate heavy-duty diesel vehicle emissions during real-world operating conditions using a transportable CVS measurement system.

Project Objective

The study was divided into two phases, a) Phase I: evaluate real-world emissions from seven heavy-duty diesel vehicles fueled by diesel and natural gas using a transportable emissions measurement system (TEMS) and a suite of portable emissions measurement systems (PEMS), b) Phase II: research multiple pathways of a passive SCR system for abatement of ammonia and NOx emissions from three-way catalyst (TWC) equipped on-road natural gas engines.

Technology Description

Phase I: Seven vehicles were tested primarily in Southern California on desert routes, freeway operation, and port drayage operation simulated at the Ports of L.A., urban delivery routes in Irvine and in Central Valley over the Interstate 99 corridor. Vehicles were tested using the TEMS, which houses a full-scale dilution tunnel with laboratory-grade emissions analyzers. In addition, the study used three different PEMS instruments, namely, Horiba OBS 2200, SEMTEC DS and the AVL MOVES system. A high-speed FTIR was used for measuring real-time greenhouse gas and ammonia emissions from the vehicles. The test routes represented real-world driving conditions in Southern California. The study included a MY 2008 diesel truck to establish baseline emissions for a non-SCR equipped vehicle.

Phase II: WVU tested three SCR formulations provided by Corning and AP Exhaust. The formulation varied in cell density and catalyst loading. The hypothesis of Phase II was to employ SCR catalyst as a passive ammonia storage system that can use the NOx slip from TWC as a source to regenerate the stored ammonia while further reducing NOx. An aging catalyst will have lower selectivity to NOx reduction and as a result have increased NOx emissions. Therefore, a passive SCR system with TWC as the onboard ammonia storage can effectively lower the NOx profile of CNG through its useful life.

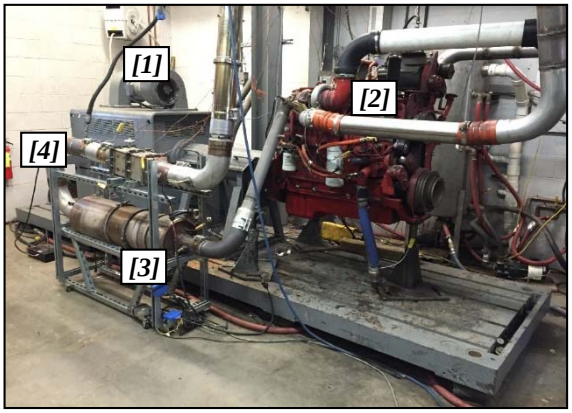


Figure 1: WVU Engine Testing Laboratory; [1] AC 300HP high speed dynamometer, [2] Cummins ISLG320, [3] Three-way Catalyst (TWC), [4] Passive selective catalyst reduction (SCR) for NH3 and NOx reduction

The project was successfully completed and the final report is being prepared. Extensive data from real-world testing of heavy-duty vehicles were collected from Phase I and a retrofit ammonia and NOx abatement technology was developed as part of Phase II.

Results

Phase I: The results show that the highway operation resulted in the lowest emissions from all vehicles. Vehicle 7 (DPF-SCR equipped) showed the lowest emissions on highway operating conditions. The near-dock operation characterized by extended idle and creep mode operation resulted in the highest NOx emissions from the diesel vehicles. The average NOx emissions of diesel vehicles using DPF and SCR were 96% lower than a MY 2008 diesel vehicle over the regional cycle. The natural gas truck emissions were 50% lower than DPF-SCR equipped diesel over the regional cycle. The natural gas vehicle (vehicle 3) showed 88% lower NOx emissions during near-dock port operation compared to the average of all DPF-SCR equipped diesel vehicles.

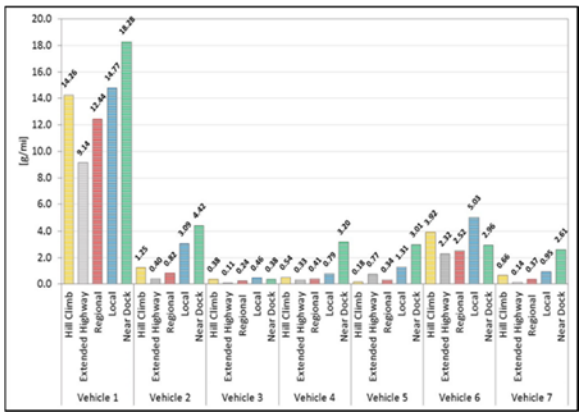


Figure 2: shows the distance-specific NOx emissions from the test vehicles over the road measured using the TEMS

Phase II: SCR 2 formulation showed the highest NOx conversion efficiency of 56.9% and the lowest NH3 reduction of 63.6%, while the SCR 3 formulation resulted in the highest NH3 reduction of 82.5%, with slight reduction in NOx conversion to 53.9% compared to SCR 2 formulation. As a further extension to this Phase, WVU is working with engine controls to change the air-fuel ratio (AFR) of the stoichiometric engine between rich mode (NH3 production mode) and lean mode (NH3 regeneration mode). It is believed that this approach could result in an engine calibration that could run on a leaner air fuel ratio for enhanced fuel economy. This could potentially increase the operating range of a stoichiometric natural gas engine.

In development of the passive SCR strategy it was found that the current pathway would vastly benefit from OEM input with engine calibrations tuned to regenerate and absorb ammonia emissions from TWC. Continuing work is done by WVU, beyond the scope of project.

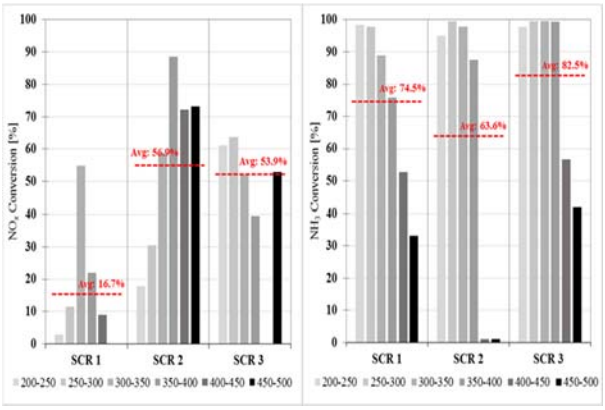


Figure 3: NOx and NH3 reduction efficiency results for varying temperature bins of three different tested zeolite SCR catalysts over an FTP cycle; [SCR 1] Iron (Fe) based low cell density zeolite catalyst, [SCR 2] Iron (Fe) based high cell density zeolite catalyst

Benefits

Phase I results show the advantages of CNG vehicles in urban goods movement applications with their low NOx characteristics. Phase II results show that a passive SCR strategy is a viable pathway to reduce simultaneously both ammonia and NOx slip from stoichiometric NG vehicles.

Project Costs

The total project cost was $490,000, with cofunding as follows: WVU, $50,000; CARB, $100,000; and SCAQMD, $390,000. The project was completed within the allocated budget.

Commercialization and Applications

The approach of frequently changing AFR to optimize ammonia and NOx reduction will also result in leaner operation of NG vehicles leading to a lower NG fuel consumption. However, implementation and commercialization of this strategy requires significant involvement by the OEM to provide calibration control of the engine. WVU proposes to approach Cummins Westport with the proposed strategy in order to evaluate its efficacy on a production engine.

SCAQMD Contract #11484 **January 2015**

Operate Truck Outreach Centers - Trucking Information Points (TIPs)

Contractor

Gladstein, Neandross & Associates LLC (GNA)
Advanced Transportation Technology & Energy Network of the California Community Colleges (ATTE)

Cosponsors

SCAQMD
U.S. DOE

Project Officer

Lori Berard

Background

The Trucking Information Points (TIPs) program is designed to reach heavy-duty truck owner-operators in the South Coast Air Basin. This demographic group was specifically targeted because they typically lack the time and resources to keep up to date on changing and developing regulations and policies that are germane to their livelihood. Outreach information includes regulations, funding opportunities, and resources to learn about advanced transportation technologies and training opportunities. To reach this group of truck owners and operators, an extensive website was created (www.tipsfortrucks.com) that links into information kiosks located at two customer service centers with support from a toll-free hotline for inquiries. The service centers are strategically located at the Port of Long Beach Terminal Access Center (TAC) and another at a truck maintenance and service center, J&R Fleet Services in Bloomington, CA, within the Inland Empire. The TIPs service centers are free-standing, computerized information kiosks equipped with connection to the tipsfortrucks.com website, touch screen browsing, and printing capabilities.

Project Objective

GNA's objective was to create bi-lingual, easy to understand terminology relating to specific regulations, funding opportunities, and advanced transportation technologies, and to place this information on the web and in easily accessible places for the target audience of small-fleet or single-truck owner-operators engaged in goods movement within the South Coast Air Basin.

The purpose of this project is to help the clientele to be better equipped to assess their regulatory status and to understand the technology and equipment solutions that they may need. Ultimately, the TIPs program will enable truck owner-operators to maintain their course of business while helping California to reach its emission reduction goals.

TIPs kiosk at J&R Fleet Servicesin Bloomington, CA

Technology Description

This project involves the design and content of an information web site (www.tipsfortrucks.com) and two stand-alone kiosks with the following components:

- Touch-screen display monitor
- Wi-Fi and hard-wire internet connection
- Internal black and white printer with paper spool

- Targeted signage displaying website prominently
- Website featuring regulatory language from the California Air Resources Board and the SCAQMD, funding opportunity descriptions for California opportunities, and advanced transportation technologies and training resources.

Status and Results

GNA has installed the kiosks at J&R Fleet Services, just east of the junction of Interstates 10 and 15 in Bloomington, California and at the Port of Long Beach, Terminal Access Center in Long Beach, California.

The website is up and running with all of the relevant information displayed in English and in Spanish. Users have been accessing the information from many locations, and new users are added each quarter.

Kiosk Usage Statistics	Quarter 1	Quarter 2
Sessions	87	20
Users	34	10
Page Views	643	109
Pages / Session	7.39	5.45
Avg Session Duration	00:03:18	00:00:48
% New Sessions	29.89%	45%

Benefits

The successful installation of the information kiosks has placed informational resources where the disparate and highly mobile target demographic group frequent and congregate the most. Whether or not the drivers have the time to browse the information where the kiosks stand, they are exposed to the web address and may access the crucial information wherever they have internet connectivity. For the purposes of outreach, this project achieves the goal of providing the best effort to support this community of drivers. For the first time, the small-fleet and single-truck owner operators have a resource to help them advance their small businesses and stay compliant.

The information is structured in a robust way where amendments and changes can be made rapidly. The way that the project is designed, there can be revisions and changes that can be 'pushed out' to the web site and kiosk in real time.

Project Costs

The original task-based fixed fee contract for the Truck Outreach Centers was for $150,000. The actual time and expenses GNA dedicated to this contract as of August 25, 2015 is $239,849.53. The extended period of time to finalize the website and kiosk content was the most critical component of the cost overruns. The timely information on technology, grant funding and regulations requires periodic updates in order to stay current and was supported by an $8,000 per quarter ($32,000 per year) budget dedicated toward this task.

Commercialization and Applications

This project has created a platform that can further extend its own outreach.

Creating a list serve

The information can be extended and pushed out to users who opt in to a list serve. This list serve can blast out emails for program announcements about events, training opportunities, changes to regulations, or announcements for funding opportunities. This will gradually build a base of users that can be reached directly.

Mobile friendly web browsing option for the website

Many of the goods movement drivers do not have computers at home, and instead use their phones to access the internet. Formatting the website for "mobile friendly" use would allow drivers greater ease of use to read the content and interact with the website when they are looking at a smaller screen.

Phone App

A phone app platform would provide the most directly accessible information on a smart phone, and would allow the program to interact with the users' phone. It would make it possible for the TIPs program to send 'push' notifications directly to the driver without the driver having to look anything up or sign onto a website. This could be very helpful for program announcements such as funding availability and important due dates and deadlines for programs and regulations.

Appendix D

List of Acronyms

LIST OF ACRONYMS

AC-absorption chiller
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
BSNOx—brake specific NOx
BMS—battery management system
CAAP—Clean Air Action Plan
CAFR—Comprehensive Annual Financial Report
CARB—California Air Resources Board
CATI—Clean Air Technology Initiative
CCF—California Clean Fuels
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
CFCI—Clean Fuel Connection, Inc.
CFD—computational fluid dynamic
CNG—compressed natural gas
CO_2—carbon dioxide
CO—carbon monoxide
CRT—continuously regenerating technology
DC—direct connection
CY—calendar year
DCM—dichloromethane
DEG—diesel equivalent gallons
DGE—diesel gallon equivalents
DF—deterioration factor
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
DRI—Desert Research Institute
ECM—emission control monitoring
EGR—exhaust gas recirculation
EPRI—Electric Power Research Institute
ESD—emergency shut down
EV—electric vehicle
FCV—fuel cell vehicle
FTA—Federal Transit Administration
FTP—federal test procedures
OBD—On-Board Diagnostics
g/bhp-hr—grams per brake horsepower per hour
GC/MS—gas chromatography/mass spectrometry
GGE—gasoline gallon equivalents
GHG—Greenhouse Gas
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
HPDI—High Pressure Diesel Injection
HT—high throughput
HTFCs-high-temperature fuel cells
HTPH—high throughput pretreatment and enzymatic hydrolysis
ICE—internal combustion engine
ICEV—internal combustion engine vehicle
ICTC—Interstate Clean Transportation Corridor
LCFS—Low Carbon Fuel Standard
Li—lithium ion
LIMS—Laboratory Information Management System
LNG—liquefied natural gas
LPG—liquefied petroleum gas or propane
LSV—low-speed vehicle
MATES—Multiple Air Toxics Exposure Study
MECA—Manufacturers of Emission Controls Association
MPFI—Multi-Port Fuel Injection
MPG—miles per gallon
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
NGV—natural gas vehicle
NHTSA—Natural Highway Traffic Safety Administration
NMHC—non-methane hydrocarbon
NO—nitrogen monoxide
NO_2—nitrogen dioxide

LIST OF ACRONYMS (cont'd)

$NO + NO_2$—nitrous oxide
NOPA—Notice of Proposed Award
NOx—oxides of nitrogen
NREL—National Renewables Energy Laboratory
OCTA—Orange County Transit Authority
OEM—original equipment manufacturer
PAH—polyaromatic hydrocarbons
PbA—lead acid
PCM—powertrain control module
PEMFC—proton exchange membrane fuel cell
PEV—plug-in electric vehicle
PHEV—plug-in hybrid vehicle
PM—particulate matter
PM2.5—particulate matter ≤ 2.5 microns
PM10—particulate matter ≤ 10 microns
ppm—parts per million
ppb—parts per billion
RDD&D (or RD3)—research, development, demonstration and deployment
RFS—renewable fuel standards
RI—reactive intermediates
RRC—rolling resistance co-efficient
RTA—Riverside Transit Agency
SCAB—South Coast Air Basin or "Basin"
SCAQMD—South Coast Air Quality Management District
SCE—Southern California Edison
SCR—selective catalytic reduction
SI—spark ignited
SIP—State Implementation Plan
SOAs—secondary organic aerosols
SoCalGas—Southern California Gas Company (A Sempra Energy Utility)
SULEV—super ultra-low emission vehicle
TAO—Technology Advancement Office
TC—total carbon
THC—total hydrocarbons
TO—task order
tpd—tons per day
TRB—Transportation Research Board
TSI—Three Squares, Inc.
UDDS—urban dynamometer driving schedule
$\mu g/m^3$—microgram per cubic meter
U.S.EPA—United States Environmental Protection Agency
U.S. —United States
ULEV—ultra low emission vehicle
VMT—vehicle miles traveled
VOC—volatile organic compounds
WVU—West Virginia University
ZEV—zero emission vehicle