



**Technology Advancement Office** | *20 Years of Progress*

Clean Fuels Program  
2007 Annual Report and  
2008 Plan Update

March 2008



South Coast  
Air Quality  
Management  
District



# South Coast Air Quality Management District

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## **EXECUTIVE SUMMARY**

### **2007 Annual Report**

The South Coast Air Quality Management District (SCAQMD) executed 67 new projects, studies or amended contracts with expenditures during Calendar Year (CY) 2007 to sponsor research, development, demonstration and deployment (RDD&D) of alternative fuel and clean fuel technologies in Southern California. Table 2 (page 17) and Table 6 (page 60) list projects which are further described in this report. The SCAQMD contributed nearly \$10 million towards such projects in partnership with other government organizations, private industry, academia and research institutes, and interested parties, with total project costs of nearly \$33 million. These projects addressed a wide range of issues and opportunities with a diverse mix of advanced technologies. The areas of technology advancement include the following:

- Infrastructure and Deployment
- Fuels and Emission Studies
- Emission Control Technologies
- Electric and Hybrid Vehicle Technologies
- Engine Technology (particularly in the heavy-duty vehicle sector)
- Mobile Fuel Cell Technologies
- Hydrogen Technology and Infrastructure
- Health Impacts Studies
- Stationary Clean Fuels Technology (including renewables)
- Outreach and Technology Transfer

During CY 2007, the SCAQMD supported a variety of projects and technologies, ranging from near-term to longer-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. Projects in CY 2007 included demonstration of emission control and retrofit technologies in off-road applications, further expansion of the natural gas alternative fueling infrastructure, development of heavy-duty natural gas engines, and additional conversions of plug-in hybrid electric vehicles. The SCAQMD also executed five health impacts studies to extend analyses of the connection between air pollution and health.

Eight research, development, demonstration and deployment projects or studies, 19 technology assessment or outreach projects, and 1 incentive project were completed in 2007, as listed in Table 5 (page 51). Summaries for the eight technical projects completed in 2007 are included in Appendix C. 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, 2008, after approval by the SCAQMD Governing Board.

### **2008 Plan Update**

The Clean Fuels Program continually seeks to support the 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 co-funding opportunity. The SCAQMD program is significant, especially at a time when both public and private funding available for technology research and development are limited. However, since national and international activities affect the direction of technology trends, the real challenge for the SCAQMD is 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 overall strategy is based in large part on technology needs identified in the Air Quality Management Plan (AQMP) and the Governing Board's directives to protect the health of residents in the South Coast Air Basin. The AQMP is the long-term "blueprint" that defines:

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

The oxides of nitrogen (NO<sub>x</sub>), volatile organic compounds (VOC), and particulate matter (PM) emission sources of greatest concern are heavy-duty on-road vehicles, light-duty on-road vehicles, and off-road equipment. 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 AQMP. Large NO<sub>x</sub> and PM<sub>2.5</sub> reductions will be necessary to meet the federal PM<sub>2.5</sub> standards by 2015, and so near- and mid-term reductions 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;
- mitigating criteria pollutant increases from renewable fuels, such as low-blend ethanol and high blend biodiesel; and
- increased activities in hybrid and plug-in hybrid technologies across light-, medium- and heavy-duty platforms.

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# CLEAN FUELS PROGRAM

## Introduction

The Basin, which comprises the Los Angeles, Orange, 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 Basin, 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 the Basin. 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, on or before March 31 of each year to the Legislature, an annual report that includes:

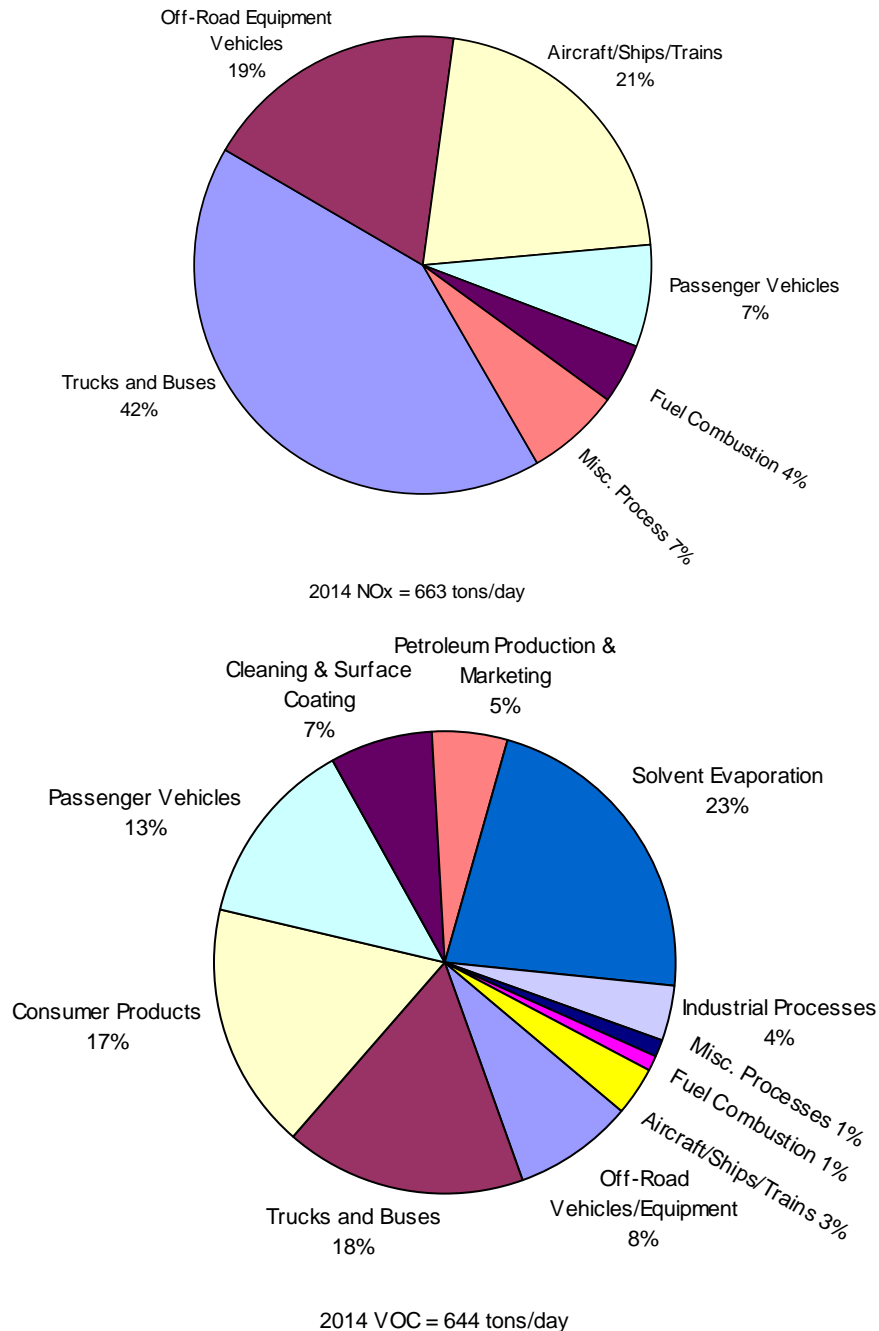
- A description of the core technologies that the SCAQMD considers critical to ensure attainment and maintenance of ambient air quality standards and a description of the efforts made to overcome barriers to commercialization of those technologies;
- An analysis of the impact of the SCAQMD's Clean Fuels Program on the private sector and on research, development, and commercialization efforts by major automotive and energy firms, as determined by the SCAQMD;
- A description of projects funded by the SCAQMD, including a list of recipients, subcontractors, co-funding sources, matching state or federal funds, and expected and actual results of each project advancing and implementing clean fuels technology and improving public health;
- 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;
- A summary of the progress made toward the goals of the Clean Fuels Program; and
- Funding priorities identified for the next year and relevant audit information for previous, current, and future years covered by the report.

This report summarizes the progress of the SCAQMD Clean Fuels Program for CY 2007. This SCAQMD program cosponsors projects to develop, demonstrate, and expedite the implementation and deployment of low-emission clean fuels and advanced 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.

During the period between January 1 and December 31, 2007, the SCAQMD executed 67 projects or studies and amended contracts that support clean fuels and advanced low-emission technologies. The SCAQMD contribution for these projects was nearly \$10 million, with total project costs of nearly \$33 million. These projects address a wide range of issues with a diverse technology mix. This report highlights achievements of the SCAQMD Clean Fuels Program in this period, summarizes project costs, and outlines future plans for the Program.

## The Need for Advanced Technologies & Clean Fuels

Achieving federal and state clean air standards in Southern California will require emission reductions from both mobile and stationary sources beyond those expected using current technologies. The need for advanced technologies and clean fuels is best demonstrated by considering the emissions inventory for the Basin and the future emissions levels projected for the 2007 Air Quality Management Plan (AQMP). The baseline 2014 emissions inventory is shown in Figure 1. Based on the 2007 AQMP, significant reductions are necessary to demonstrate attainment with the federal standards.



**Figure 1: Major Source Contributions (2014)**

To fulfill long-term emission reduction measures, the 2007 AQMP relies on advanced technologies that are not yet fully developed for commercial use. Significant reductions are anticipated from implementation of advanced control technologies for both on-road and non-road mobile sources.

In addition, the new air quality standards for ozone (0.08 ppm, 8-hour average) and fine particulate matter, promulgated by the U.S. Environmental Protection Agency (U.S. EPA) in 1997, are projected to require additional long-term controls for both NO<sub>x</sub> and VOC.

Recent health studies also indicate a greater need to reduce NO<sub>x</sub> emissions and toxic air contaminant emissions. More importantly, the California Air Resources Board (CARB) listed diesel exhaust emissions as a toxic air contaminant in 1998. Subsequently, in 1999, the SCAQMD completed the Multiple Air Toxics Exposure Study (MATES-II) and found that diesel combustion sources (primarily from heavy-duty vehicles) contribute approximately 70 percent to the estimated potential cancer risk from air toxics in the Basin. A follow-on study, MATES-III, which was initiated in Spring 2004 and ended in 2007, was undertaken to evaluate air toxic exposure trends, expand the list of known air toxics, and assess local impacts from industrial, commercial and mobile sources. Initial results have shown a decrease in stationary emitted air toxics, but continued high levels of emissions from mobile, specifically diesel sources. The MATES III draft report was issued in January 2008 and the final is anticipated to be approved in April 2008. The results will be used to determine appropriate control strategies for reducing public exposures to these toxics.

In addition, there are increasing concerns over greenhouse gas emissions and petroleum dependence arising from the heavy use of conventional technologies. In recognition of these concerns, the federal government has several programs (the Hydrogen, Fuel Cells, and Infrastructure Technologies Program, and the FreedomCAR and Vehicle Technologies Program) to investigate and develop increased efficiency and alternative fuel (namely hydrogen) technologies. Similarly, the state has adopted goals to reduce long-term dependence on petroleum-based fuels (AB 2076) and transition to alternative fuels based on life-cycle analyses (AB 1007).

California's Governor took this concern one step further when in January 2007 he established a Low-Carbon Fuel Standard (LCFS) by Executive Order. This GHG standard for transportation fuels will necessitate increased research into alternatives to oil and traditional fuels. The LCFS came out of AB 32, the "Global Warming Solutions Act," which was signed by the Governor in fall 2006 and requires California's greenhouse gas emissions to be capped at 1990 levels by 2020.

It is clear that clean, 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; reduce long-term dependence on petroleum-based fuels; and support a more sustainable energy future. To help meet this need for advanced, clean technologies, the SCAQMD Governing Board continues to promote the Clean Fuels Program through the Technology Advancement Office. This 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, the SCAQMD Technology Advancement Office has co-funded projects in cooperative partnership with private industry, technology developers, academic and research institutes, and local, state, and federal agencies. Funding for the program and the public-private partnerships are described in the next section.

## Program Funding

The Clean Fuels Program, under California Health and Safety Code (H&SC) Sections 40448.5 and 40512 and Vehicle Code Section 9250.11, establishes mechanisms to collect revenues from mobile and stationary sources to support the program's objectives and identifies the constraints on the use of

the funds. In 2003 these funding mechanisms, described below, were reauthorized through January 1, 2010, under SB 288 (Sher). The objective of the Program is to support and promote projects to increase the utilization of clean-burning alternative fuels and related technologies, such as hydrogen, fuel cells, liquid petroleum gas, natural gas, combination fuels, synthetic fuels, electricity including electric and hybrid vehicles, as well as unique applications of conventional fuels and other clean alternatives yet to be developed.

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 2007 the funds available through each of these mechanisms were as follows:

- Mobile sources (DMV revenues) \$ 12,289,209
- Stationary sources (emission fee surcharge) \$ 377,483

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 California Energy Commission (CEC), the U.S. EPA, the U.S. Department of Energy (DOE), and the U.S. Department of Transportation (DOT). These supplemental revenues depend in large part on the originating agency, its budgetary and planning cycle, and the specific project or intended use of the revenues.

Table 3 lists the supplemental grants and revenues recognized in 2007.

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 more than \$3 of outside funding for each \$1 of SCAQMD funding. Through this 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. The SCAQMD's Clean Fuels Program has also avoided duplicative efforts by coordinating and jointly funding projects with major funding agencies and organizations.

## 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 interests. The Technology Advancement Advisory Group, whose members are listed in Appendix A, serves:

- to coordinate the SCAQMD program with related local, state, and national activities;
- to review and assess the overall direction of the program; and
- to identify new project areas and cost-sharing opportunities.

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, 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. The members of the SB 98 Clean Fuels Advisory Group are also listed in Appendix A.

The review process of the Clean Fuels Program now includes several meetings of the two Advisory Groups, review by the Technology Committee of the SCAQMD Board, public hearing of the Annual Report and Plan Update before the full SCAQMD Governing Board, and submittal of the Annual Report to the Legislature.

## Core Technologies

The broad technology areas of focus for the Clean Fuels Program are listed below:

- Infrastructure and Deployment
- Emission Control Technologies
- Electric and Hybrid Vehicle Technologies
- Engine Technologies
- Mobile Fuel Cell and Hydrogen Technologies
- Stationary Clean Fuels Technologies

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

- 1) Low- 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. Although the SCAQMD program is significant, especially at a time when both public and private funding available for technology research and development are limited, 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. 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.

Given the diversity of sources that contribute to the air quality problems in the Basin, there is no single technology that can solve all of the problems. Thus, the core technologies represent a variety of applications with full emissions benefit “payoffs,” i.e., perceived time to full commercialization and mass deployment, occurring at different times. 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 NO<sub>x</sub> technologies and clean energy alternatives such as fuel cells, solar power, and other renewable energy systems.

Specific projects are selected for co-funding from competitive solicitations, cooperative agency agreements, and unsolicited proposals. Criteria considered in project selection include emissions

reduction potential, technological innovation, potential to reduce costs and improve cost effectiveness, contractor experience and capabilities, overall environmental impact or benefit, 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 AQMP needs for achieving clean air are briefly described below.

### **Infrastructure and Deployment**

A key element for the widespread acceptance and resulting increased use of alternative fueled vehicles 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 natural gas, alcohol-based fuels, propane, hydrogen, hydrogen-natural gas mixtures, and even electricity are much less available or accessible. To realize the emissions reduction benefits, the alternative fuel infrastructure 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.

### **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 and to a lesser extent with the SCAQMD.

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, selective catalytic reduction (SCR), and emulsified fuels 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. The CARB, U.S. EPA, and the SCAQMD have also promulgated regulations that lower the sulfur content of diesel fuels.

### **Electric and Hybrid Vehicle Technologies**

There has been an increased level of activity and attention on hybrid vehicles due to a confluence of factors, including the highly successful commercial introductions of hybrid passenger vehicles by Toyota, Honda, and Ford, increases in and variability of oil prices, and increased public attention on global warming. A Technology Review of the California Zero Emission Vehicle (ZEV) regulation conducted by CARB in the fall of 2007 suggests several changes to the regulation. In concept, while the volume of fuel cell vehicles expected from the major automakers by 2008 (250) and by 2011 (2,500) is still expected, the proposal offers an alternative strategy utilizing additional plug-in hybrid electric vehicles (PHEVs) or “silver plus” vehicles, such as PHEVs and hydrogen-fueled internal combustion engine (ICE) vehicles.

Due to these factors, there is a window of opportunity to leverage state and federal activities to accelerate the development and deployment of such advanced hybrid technologies, including PHEV



deployment, medium- and heavy-duty hybrid vehicles, energy storage technologies, hybrid emission certification cycle development, battery durability testing, and 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, ethanol, and hydrogen) and propulsion systems (e.g., ICEs and fuel cells).

### **Engine Technologies**

Medium- and heavy-duty on-road vehicles contributed approximately 30% of the Basin's NO<sub>x</sub> in 2005. More importantly, on-road heavy-duty diesel engines contributed almost 50% of the on-road mobile source PM<sub>2.5</sub>, which has known toxic effects. These figures notably do not include the significant contribution from off-road mobile sources. In fact, CARB's off-road 2006 emission model estimates that diesel-powered off-road construction equipment alone emits 120 tons per day of NO<sub>x</sub> and 7.5 tons per day of PM emissions in the Basin. 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 NO<sub>x</sub> and particulate emissions. The current NO<sub>x</sub> emissions standard for heavy-duty engines is 1.2 g/bhp-hr (combined NO<sub>x</sub> and VOC emissions), and there is currently only one heavy-duty natural gas engine with demonstrated NO<sub>x</sub> emissions levels at 0.2 g/bhp-hr (Cummins 8.9L). The SCAQMD, along with various local, state and federal agencies, continues to support the development and demonstration of alternative fueled heavy-duty engine technologies, using compressed natural gas (CNG) and liquefied natural gas (LNG) for applications in transit buses, school buses, and refuse collection and delivery vehicles to meet future federal emissions standards.

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

Most of the automobile manufacturers have conceded that mass commercial introduction of fuel cell vehicles (FCVs) are likely to be delayed due to the cost, durability, and infrastructure issues associated with hydrogen and fuel cells. The SCAQMD continues to support the infrastructure required to refuel these demonstration fuel cell vehicles but is also actively engaged in finding alternatives to the costly and potentially longer term fuel cell power plant. As mentioned previously, plug-in hybrid technology could help enable fuel cells by reducing the size and complexity of the vehicle. Further bridging technologies being investigated are hybrid or plug-in hybrid hydrogen ICE vehicles and hydrogen-CNG blended ICE vehicles.

### **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, and bio-mass conversion. Although combustion sources are lumped together as stationary, the design and operating principles vary significantly. Included in the stationary category are boilers, heaters, gas turbines, and reciprocating engines. Boilers and heaters vary in size, heat input, process conditions, and operating ranges. Gas turbines vary greatly in size and application and are typically natural gas-fired with add-on controls to clean up the flue gas. Stationary ICEs can be either rich-burn or lean-burn. The core technologies for this category focus on using advanced combustion processes, development of catalytic add-on controls, and alternative fuels and technologies.

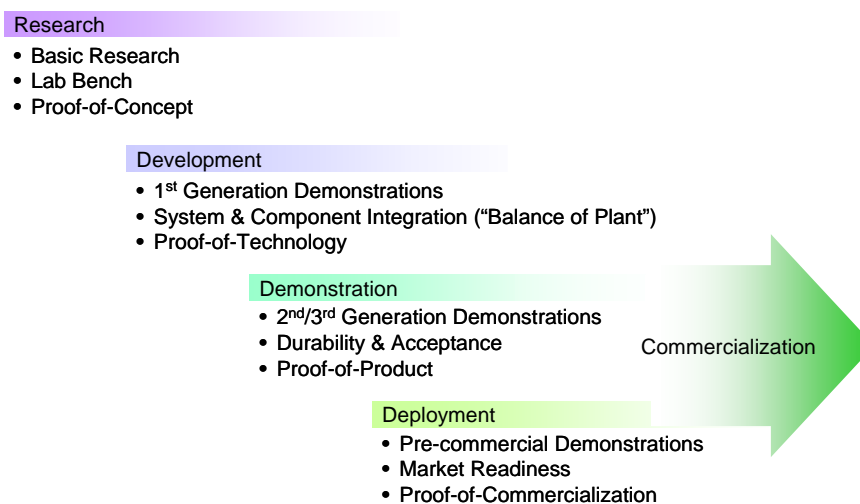


## PROGRAM IMPACT

### Expected Benefits of the Clean Fuels Program

To reap the maximum emissions benefits from any technology, widespread deployment and thus end-user acceptance must occur. The product manufacturers must overcome technical and market barriers to ensure a competitive and sustainable business. Unfortunately, the time can be long and the costs high to address these technical and market barriers, discouraging both manufacturers and end-users from considering advanced technologies. A combination of real-world demonstrations, education, outreach, and regulatory impetus and incentives is necessary to catalyze new, clean technologies. The Clean Fuels Program addresses several of these aspects by co-funding research, development, demonstration, and deployment projects to share the risk of emerging technologies.

Figure 2 provides a conceptual diagram 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 variety of emissions benefit payback timing, but also to proliferate technology choices.



**Figure 2: Clean Fuels Program Project Types**

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. However, a good indication of the impact and benefits of the Clean Fuels Program overall is provided by a brief list of sponsored projects which have resulted in commercialized products or helped to advance the state-of-the-technology.

- CNG Engine Development for Heavy-Duty Vehicles
  - Westport Innovations: ISX 15L (LNG)
  - Cummins Westport: C8.3L (CNG, LNG), B5.9L (CNG) L10 (CNG), ISL 8.9L (CNG, LNG)
  - 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);
  - ISE/ThunderPower Fuel Cell Bus; and
  - Commercial Stationary Fuel Cell Demonstration with UTC and SoCalGas (first of its kind).
- Electric and Hybrid Electric Vehicle Development and Demonstrations
  - EPRI hybrid vehicle evaluation study
  - Hybrid electric vehicle demonstrations with SCE, UC Davis, and AC Propulsion;
  - Electric vehicle demonstrations with Santa Barbara Bus Works, Toyota, and GM; and
  - Plug-in Hybrid Electric Van with EPRI, DaimlerChrysler, and SCE.
- Aftertreatment Technologies for Heavy-Duty Vehicles
  - Johnson Matthey and Engelhard trap demonstrations on buses and construction equipment; and
  - Lubrizol optimization and demonstration of oxidation catalysts on CNG, heavy-duty vehicles.

The benefits of these technologies, however, could not have been achieved unless all stakeholders (i.e., manufacturer, end-users, and government) collectively worked to overcome the technology, market, and project-specific barriers encountered at every stage of the research, development, demonstration, and deployment process.

## Overcoming Barriers

Commercialization and implementation of advanced technologies come with a variety of real-world challenges and barriers. These include project-specific issues as well as general technology concerns.

### **Project-Specific Issues**

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

### **Technology Implementation Issues**

- 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

Other barriers include reduced research budgets, infrastructure and energy uncertainties, sensitivity to multi-media environmental impacts, and the need to find balance between environmental and

economic needs. In order to address these barriers, the SCAQMD seeks to establish relationships with the stakeholders through unique public-private partnerships involving industry, end-users, and other government agencies. 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 institutions 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, coordination of infrastructure needs, and facilitation of standards setting and educational outreach. There is also synergy in developing technologies that address multiple goals of public and private bodies regarding the environment, energy, and transportation.

The SCAQMD actively seeks additional partners for the program through participation in various working groups, committees, and task forces. This participation has resulted in coordinating 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. Additionally, this list 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 the 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, such as the Manufacturers of Emission Controls Association (MECA), the California Fuel Cell Partnership, the California Stationary Fuel Cell Collaborative, and the California Natural Gas Vehicle Partnership.

The coordination efforts with these various stakeholders have resulted in a number of cosponsored projects. The descriptions of the contracts executed in CY 2007 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 manufacturers. Such partnerships are essential to address commercialization barriers and help expedite the implementation of advanced low-emission technologies. Listed in Table 1 are the funding agency partners and major 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, smaller manufacturers, and project participants who make important contributions critical to the success of the SCAQMD program. These partners are identified in the more detailed Project Summaries section.

**Table 1: SCAQMD Funding Partners in CY 2007**

Research Funding Organizations	Major Manufacturers/Providers
California Air Resources Board National Inst. of Environmental Health Services National Renewable Energy Laboratory Southern California Gas Company U.S. Department of Energy	Clean Energy Fuels Corporation City of Los Angeles Emissions Solutions, Inc. Johnson Matthey Inc. Orange County Transportation Authority Port of Los Angeles Port of Long Beach Quantum Fuel Systems Technologies

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 2007. Such examples are provided in the following sections on Technology Advancement’s Research, Development, and Demonstration projects and Technology Deployment and Commercialization efforts.

### Research, Development and Demonstration

Important examples of the impact of SCAQMD research and development coordination efforts are: (a) the development and demonstration of heavy-duty engines; and (b) the further development of plug-in hybrid and electric vehicle technologies.

#### Heavy-Duty Engines

Heavy-duty vehicles contribute the majority of NO<sub>x</sub> and particulate emissions in the South Coast Air Basin. The SCAQMD has a long history of supporting clean conventional and alternative fuel strategies for this sector of the mobile inventory. One project contracted during CY 2007 is to develop natural gas engines capable of meeting the stringent 2010 federal emissions standards. Emissions Solutions Inc. proposes to develop, demonstrate and certify a 7.6L heavy-duty natural gas engine that could be used in both the repower of existing diesel engines as well as in new vehicles that meet the 2010 heavy-duty engine NO<sub>x</sub> standard.

#### Plug-in Hybrid and Electric Vehicles

The SCAQMD has actively sponsored the development of PHEVs for light-duty and medium-duty platforms. For the light-duty application, the SCAQMD has funded a \$2 million project with



**Figure 3: Electric Tow Tractor**

Quantum Fuel Systems Technologies to convert 20 new Ford Escape Hybrid vehicles to plug-in hybrid electric vehicles using advanced lithium-ion battery systems and controls.

The SCAQMD has also partnered with the Port of Los Angeles to develop and demonstrate an electric tow tractor for transporting containers from shipping terminals to nearby warehouses. The air pollutant

contribution caused by goods movement is becomingly increasingly evident and needs to be addressed through the development of new and improved technologies. This project awarded to Balqon Corporation is to develop a tractor that will provide sufficient torque and power to tow a 60,000-pound container. The tractor will include a fast-charging battery with a 40-mile per charge range and zero emissions.

## 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. This is accomplished through a unique public-private partnership where the risks and costs of developing and demonstrating promising technologies and clean-burning fuels are shared with industry. 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 2007 reporting period illustrate the impact of SCAQMD technology deployment and commercialization efforts.

### Demonstrate Emission Controls on Off-Road Diesel Construction Equipment

There are nearly 70,000 pieces of diesel-powered off-road construction equipment operating in the Basin. As mentioned earlier, CARB’s off-road 2006 emission model estimates that 120 tons per day of NO<sub>x</sub> and 7.5 tons per day of PM emissions are produced by this equipment. In 2007, the SCAQMD cosponsored the demonstration of SCR technology for NO<sub>x</sub> and PM emissions control on heavy-duty diesel construction equipment. Engine, Fuel, and Emissions Engineering, Inc. (EFEE) will design, install, and demonstrate SCR technology on heavy-duty diesel construction equipment at the Los Angeles County Sanitation District Puente Hills landfill. The project could potentially reduce NO<sub>x</sub> emissions by 80% and PM emissions by 30% in these types of equipment.



**Figure 4: Equipment without Aftertreatment**



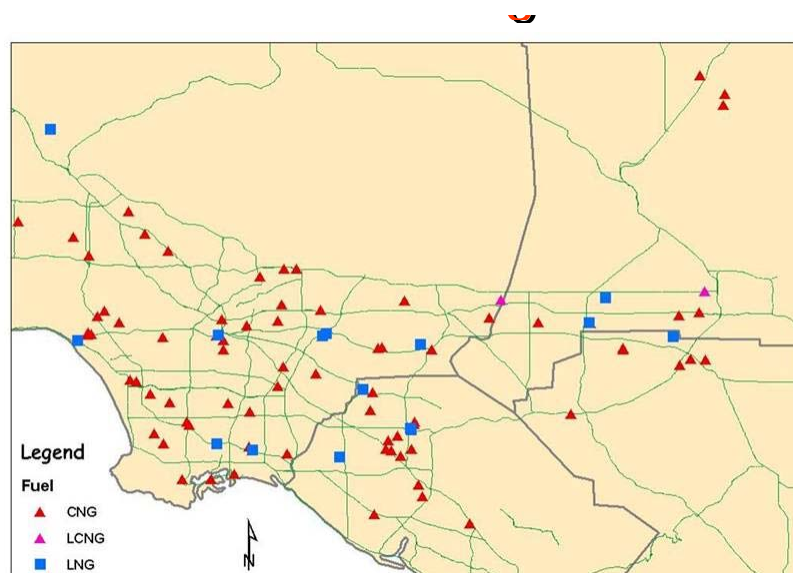
**Figure 5: Equipment with Aftertreatment**

In July 2007, CARB approved its “In-Use Off-Road Diesel Vehicles” regulation to address diesel vehicles, including off-road construction vehicles. CARB estimates that the regulation will prevent 4,000 premature deaths and at its peak retrofit up to 100,000 vehicles. However, the regulation is only enforceable if verified devices are available on the market. The MSRC, working closely in conjunction with CARB, developed a broad-based “Showcase” program to demonstrate and ultimately verify diesel emission control retrofit systems on heavy-duty off-road diesel construction equipment. The MSRC and CARB worked closely together to match compatible diesel emissions control devices with appropriate off-road construction equipment and ranked devices and equipment to achieve the broadest demonstration across vehicle classes. The MSRC’s “Showcase” Program

ultimately provided more than \$3.6 million in funding for 16 manufacturers producing 30 devices and 18 equipment owners with 230 off-road vehicles. The MSRC's Program, however, focused solely on devices that reduced PM emissions. To address the NO<sub>x</sub> component, the SCAQMD is providing funding to demonstrate devices that reduce both PM and NO<sub>x</sub> emissions, which typically have a higher cost. In late 2007, the SCAQMD Board approved 11 projects totaling more than \$1.2 million for 11 fleets and 32 pieces of equipment. The emissions reductions achieved from these projects and the MSRC's "Showcase" will be considerable, but most importantly they will result in the commercialization of verified retrofit equipment for off-road construction equipment and allow CARB to implement its In-Use Off-Road Diesel Vehicle regulation.

### Natural Gas Infrastructure and Deployment

In 2007, the SCAQMD continued to aggressively add and upgrade natural gas refueling facilities to support the need for CNG and LNG fuel by fleet operators subject to clean fuel fleet requirements. In fact, contracts were executed in 2007 for natural gas infrastructure and deployment exceeding \$1.5 million or 15% of the funds executed for this reporting period. The map below shows the distribution of natural gas infrastructure throughout the South Coast Air Basin (SCAB). Currently, there are 100 CNG refueling stations and 18 LNG refueling stations. Of the 18 LNG refueling stations, half of them are L/CNG, which means they can refuel either liquid or compressed NG.



**Figure 6: Natural Gas Refueling Facilities within the SCAB**

### Health Impacts Studies

The SCAQMD also executed five projects totaling more than \$1.4 million to participate in several broad health impacts studies including evaluating particulate matter toxicity, understanding actual exposure levels in communities with multiple air pollution sources, and measuring the effects of goods movement on port community children. The findings can be used to more accurately determine the health benefits of using alternative and advanced technologies to reduce diesel emissions.



## 2007 PROJECT EXPENDITURES

The SCAQMD Clean Fuels Program follows a “technology-driven” approach, supporting 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, 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 Governing Board.

As projects are approved by the Governing Board and executed into contracts every month, the finances necessarily change to reflect these projects. As such, the following represents the status of the Clean Fuels Fund as of December 31, 2007.

### Financial Summary

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, 2007, a total of 67 contracts, projects or studies that support clean fuels were executed or amended, as shown in Table 2. The major technology areas summarized are: infrastructure and fuel production, fuels/emission studies, emission control technology, electric and hybrid technologies, engine technology, hydrogen technology and infrastructure, fuel cell technology, health impacts studies, stationary clean fuel technology, and outreach and technology transfer. The distribution of funds based on technology area is shown graphically in Figure 7. 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 expenditures that were contracted or amended for the 2007 reporting period are shown below with the total project costs:

• SCAQMD Clean Fuels Fund Contribution	\$ 9,893,039
• Total Cost of Clean Fuels Projects	\$ 32,931,303

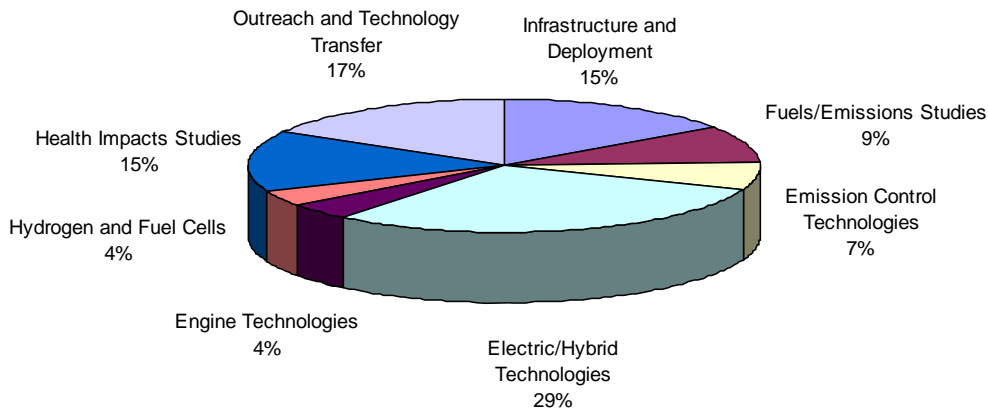
Each year, the Governing Board approves funds to be transferred to the General Fund Budget for Clean Fuels administration. For 2007, the Board transferred \$600,000 for workshops, conferences, co-sponsorships and outreach activities as well as postage, supplies, and costs for special conferences. Only the funds committed by December 31, 2007, are included within this report. Any portion of the Clean Fuels Funds not spent by the end of Fiscal Year 2007-08 ending June 30, 2008, will be returned to the Clean Fuels Fund.

Partially included with the SCAQMD contribution are supplemental sponsorship revenues from various organizations that supported these technology advancement projects. This supplemental revenue is listed in

Table 3. Appendix B lists all Clean Fuels Fund contracts that were open and active as of January 1, 2008.

For Clean Fuels executed or amended contracts in 2007, the average SCAQMD contribution is approximately 30 percent of the total cost of the projects, identifying that each dollar from the SCAQMD was leveraged with nearly three dollars of outside investment.

During 2007, the SCAQMD executed contracts, projects, studies or contract amendments with expenditures of nearly \$10 million for Clean Fuels projects. The distribution of funds for executed contracts is shown in Figure 7 below.



**Figure 7: Distribution of Funds for Executed Clean Fuels Projects  
CY 2007 (\$9.9 million)**

## Review of Audit Findings

State law requires the SCAQMD undergo a standard, annual financial audit after the closing of each fiscal year. The financial audit is conducted by an independent accounting firm selected through a competitive bid process. For the fiscal year ended June 30, 2007, the firm of Thompson, Cobb, Bazilio & Associates, P.C. conducted the financial audit. As a result of this financial audit, a Comprehensive Annual Financial Report (CAFR) was issued. The CAFR noted there were no adverse internal control weaknesses with regard to SCAQMD financial statements, which include the Clean Fuels Program revenue and expenditures. Thompson, Cobb, Bazilio & Associates, P.C. gave the SCAQMD an “unqualified opinion,” which is the highest possible financial rating. Notably, the SCAQMD has achieved this rating on all prior annual financial audits.

**Table 2: Contracts Initiated or Amended between January 1 and December 31, 2007**

<b>Contract</b>	<b>Contractor</b>	<b>Project Title</b>	<b>Start Term</b>	<b>End Term</b>	<b>AQMD \$</b>	<b>Project Total \$</b>
<b>Infrastructure and Deployment</b>						
06017	Fuelmaker Corporation	Incentive Buydown Program for CNG Home Refueling Appliance	09/26/05	03/31/08	250,000	250,000
06018	American Honda Motor Co., Inc.	Incentive Buydown Program for CNG Home Refueling Appliance	11/02/05	03/31/08	(250,000)	(250,000)
07149	City of San Bernardino	Purchase & Install New Public Access LNG-L/CNG Refueling Station at City of San Bernardino Municipal Service Yard	06/25/07	12/31/12	164,861	1,399,110
07151	Menifee Unified School District	Purchase & Install New Public Access CNG Refueling Station	01/25/07	12/31/12	75,000	414,500
07152	Newport-Mesa Unified School District	Purchase & Install New Limited Public Access CNG Refueling Station	05/16/07	12/31/12	150,000	375,000
07243	City of Commerce	Purchase & Install New Public Access L/CNG Refueling Station	05/16/07	12/31/12	250,000	1,300,000
07244	SunLine Transit Agency	Upgrade Existing Public Access CNG Refueling Stations in Thousand Palms & Indio	04/04/07	12/31/12	90,000	180,000
07253	Colton Joint Unified School District	Local Match to Purchase & Install CNG Refueling Station	03/19/07	05/15/08	170,000	1,348,408
07320	Orange County Transportation Authority	Install New CNG Refueling Station in the City of Santa Ana	12/21/07	12/31/12	350,000	5,841,729
08033-1	California Air Resources Board	Demonstrate LPG Stop-Fill Unit	06/25/07	06/24/10	75,000	498,900
08101	Pupil Transportation Cooperative	Upgrade Existing Public Access CNG Refueling Station	12/31/07	12/31/13	187,154	300,000
<b>Fuels/Emission Studies</b>						
06086	West Virginia University	Perform Emissions Testing of up to Four Cleaire Longview Systems on Waste Collection Vehicles	01/17/07	04/30/09	180,000	180,000
07054	West Virginia University	Conduct In-Use Emissions Testing of Refuse Trucks	12/31/06	05/31/08	500,000	500,000
07341	Southwest Research Institute	Remote Sensing of Heavy-Duty Engines including Locomotives	06/29/07	12/31/07	70,000	140,000
08033-2	California Air Resources Board	Test Particulate Measurement Device for In-Use Vehicles	06/25/07	06/24/10	125,000	504,514
<b>Emission Control Technologies</b>						
07236	National Renewable Energy Laboratory	Investigate the Role of Lubricating Oil on Particulate Matter Emissions from Vehicles	03/23/07	08/31/08	200,000	446,887
08033-3	California Air Resources Board	Demonstrate Retrofit SCR System for NOx Emission Reduction Using Crystalline Matrix Storage for Ammonia	06/25/07	06/24/10	78,500	338,268
08068	Johnson Matthey Inc.	Develop & Demonstrate SCR Technology for NOx and PM Emissions	12/14/07	01/31/09	254,000	655,500

**Table 2: Contracts Initiated or Amended between January 1 and December 31, 2007 (cont'd)**

<b>Contract</b>	<b>Contractor</b>	<b>Project Title</b>	<b>Start Term</b>	<b>End Term</b>	<b>AQMD \$</b>	<b>Project Total \$</b>
<b>Emission Control Technologies (cont'd)</b>						
08161	Engine, Fuel & Emissions Engineering, Inc.	Demonstrate NOx & PM Emissions Control on Construction Equipment	12/31/07	02/28/09	135,830	330,850
<b>Electric/Hybrid Technologies</b>						
99109	Toyota Motor Credit Corporation	Three-Year Lease of One RAV4 Electric Vehicle	04/04/99	01/01/08	7,794	7,794
07265	Descanso Gardens	Demonstrate Electric Tram	04/20/07	07/19/08	96,000	121,000
07293	Balqon Corporation	Develop & Demonstrate Electric Tow Tractor for Transportation Containers from Shipping Terminals	04/27/07	05/31/08	527,000	527,000
08063	Quantum Fuel Systems Technologies Worldwide, Inc.	Develop & Demonstrate 20 Plug-In Hybrid Electric Vehicles	12/31/07	12/15/14	2,095,613	2,815,266
08067	Calstart	Demonstrate Hydraulic-Hybrid Shuttle Bus	10/30/07	03/31/10	250,000	1,210,000
<b>Engine Technologies</b>						
07306	Emission Solutions, Inc.	Develop, Demonstrate & Certify Heavy-Duty Natural Gas Engine Meeting 2010 Emission Standards	06/28/07	07/31/08	400,000	1,200,000
<b>Mobile Fuel Cell Technologies</b>						
04126	American Honda Motor Co., Inc.	Lease of One Additional Honda Fuel Cell Electric Vehicle	06/22/04	05/23/08	10,825	10,825
07356	ISE Research Corporation	Upgrade & Demonstrate Fuel Cell Bus	11/02/07	08/31/09	325,000	1,285,000
<b>Hydrogen Technology and Infrastructure</b>						
Purchase Order	Hydrogenics Corporation	Refurbish Hydrogen Refueling Station at SCAQMD Headquarters in Diamond Bar	06/12/07	07/31/07	43,000	43,000
<b>Health Impacts Studies</b>						
07181	California Air Resources Board	Physical, Chemical & Toxicological Assessment of the Semi-Volatile & Non-Volatile Fraction of PM	01/17/07	04/01/10	338,975	667,950
07196	California Air Resources Board	Environmental Justice Saturation Monitoring of Selected Pollutants in Wilmington, CA	01/17/07	12/31/08	100,000	400,000
07359	University of Southern California	Study on Combustion Exhaust and Respiratory Health of Port Community Children	12/14/07	08/31/08	489,300	2,989,300
08033-4	California Air Resources Board	Spatiotemporal Analysis of Air Pollution and Mortality in California Based on the American Cancer Society Cohort	06/25/07	06/24/10	374,988	749,976

**Table 2: Contracts Initiated or Amended between January 1 and December 31, 2007 (cont'd)**

<b>Contract</b>	<b>Contractor</b>	<b>Project Title</b>	<b>Start Term</b>	<b>End Term</b>	<b>AQMD \$</b>	<b>Project Total \$</b>
<b>Health Impacts Studies (cont'd)</b>						
08033-5	California Air Resources Board	Extended Analyses of Air Pollution & Cardiopulmonary Disease in the California Teachers Study Cohort	06/25/07	06/24/10	142,326	284,652
<b>Outreach and Technology Transfer</b>						
97113	JME Inc.	Review & Assessment of Technical Proposals Regarding ATTB Ultracapacitor System	05/08/97	03/31/09	15,000	15,000
05008	Bevilacqua-Knight Inc.	Participate in California Fuel Cell Partnership for FY 2007 & Provide Support for Regional Coordinator	07/07/04	07/06/08	133,800	2,293,274
05127	Protium Energy Technologies	Technical Assistance for Development, Outreach & Commercialization of Hydrogen & Fuel Cell Applications	03/14/05	03/31/08	20,000	20,000
06061	Saint Malo Solutions	Consulting Services in Preparation of Mobile Source Emissions Element of 2007 AQMP	05/17/06	03/31/08	40,000	40,000
07059	Dowling Associates, Inc.	Technical Assistance Related to Air Quality Impacts of Regional Goods	12/19/06	11/30/08	10,000	10,000
07130	Burnett & Burnette	Technical Assistance with CNG Technology	01/17/07	12/31/08	40,000	40,000
07185	Joseph C. Calhoun, P.E., Inc.	Technical Assistance for Development, Outreach & Commercialization of Advanced Low-Emission Vehicle Technologies	01/29/07	01/31/08	20,000	20,000
07241	Charles Wyman, Ph.D.	Technical Assistance for Cellulosic Ethanol Forum & Roundtable	02/24/07	07/31/07	7,300	7,300
07247	TIAX LLC	Technical Assistance with Low-Emission and Alternative Fuels Technologies	03/19/07	12/31/08	50,000	50,000
07257	Michael Studer, Ph.D.	Technical Assistance for Forum & Roundtable on Cellulosic Ethanol	04/11/07	07/31/07	1,000	1,000
07262	Judith Lamare	Technical Assistance for Smog Check Technology Forum & Roundtable	03/16/07	07/31/07	12,000	12,000
07314	Engine, Fuel & Emissions Engineering, Inc.	Technical Assistance with Advanced Heavy-Duty and Off-Road Technologies	06/25/07	12/31/09	60,000	60,000
07342	Douglas R. Lawson	Technical Assistance for Mobile Source Technologies	06/21/07	08/31/08	15,000	15,000
Direct	Payment from Clean Fuels	Co-Host CAPCOA's The Future is Green Conference & Expo in September 2008	09/18/07	09/18/08	50,000	500,000
Transfer	Transfer from Clean Fuels	Participate in California Natural Gas Vehicle Partnership	02/02/07	02/02/08	25,000	250,000

**Table 2: Contracts Initiated or Amended between January 1 and December 31, 2007 (cont'd)**

<b>Contract</b>	<b>Contractor</b>	<b>Project Title</b>	<b>Start Term</b>	<b>End Term</b>	<b>AQMD \$</b>	<b>Project Total \$</b>
<b>Outreach and Technology Transfer (cont'd)</b>						
Transfer	Transfer from Clean Fuels	Return Funds Received from LADWP Settlement Fund in CY 2003 to Re-allocate to City of Los Angeles Million Trees Initiative	09/07/07	09/07/07	933,050	933,050
Varies	Various Contractors	Co-Sponsorships of 18 Conferences, Workshops and Events, plus 3 Memberships	Varies	Varies	204,723	1,599,250

**Table 3: Supplemental Grants/Revenue Received between January 1 and December 31, 2007**

<b>Revenue Agreement</b>	<b>Revenue Source</b>	<b>Project Title</b>	<b>Contractor</b>	<b>SCAQMD Project</b>	<b>Total</b>
Contract #07255	CARB	Investigate the Role of Engine Lubrication on PM Emissions from Mobile Sources	National Renewable Energy Lab	Contract #07236	\$100,000
Contract #07270	City of Los Angeles, Dept. of Public Works, Bureau of Sanitation/Solid Resources	In-Use Emissions Testing of Refuse Trucks	West Virginia University Research Corporation	Contract #07054	\$500,000
Contract #07300	City of Angeles, Port of Los Angeles	Develop & Demonstrate Electric Tractor Tow for Transporting Containers from Shipping Terminals	Balqon Corporation	Contract #07293	\$263,500
Direct Deposit	Mack Trucks Inc.	Develop, Demonstrate & Certify Heavy-Duty Natural Gas Engine Meeting 2010 Emission Standards	Emissions Solutions, Inc.	Contract #07306	\$50,000









SunLine's two CNG stations are among the highest volume stations in the Southern California area. Over the last four years, SunLine has had complaints with 3,600 psig vehicle customers because the CNG public refueling stations cannot full fuel these vehicles to about 4,200 psig temperature compensated during the summer months. SunLine recently evaluated the existing stations and determined that it was necessary to upgrade the public and private CNG stations to increase the pressure of the fuel system from 3,000 psig to 3,600 psig. Currently, all new CNG vehicles are designed with the 3,600 psig option and 100% of all CNG vehicles in the Coachella Valley are designed with 3,600 psig. SunLine proposed to upgrade and retrofit the refueling systems at both their Thousand Palms and Indio stations. The upgrades will enable the public stations to accommodate vehicles with the 3,600 psig, as well as enable SunLine to retrofit the transit only refueling stations to accommodate new buses purchased in 2006. The projects included adding a third dispenser to meet 3,600 psig at the internal transit bus refueling island, connecting the new dispenser to an existing card reader, removing one of the six CNG 4,000 psig storage vessels (10,000 scf each) and replace a 4,000 psig bottle with one each 5,500 and 12,000 scf psig bottle for full filling temperature compensated to 3,600 psig.

**07253: Local Match to Purchase & Install CNG Refueling Station**

Contractor: Colton Joint Unified School District  
SCAQMD Cost-share: \$ 170,000

Cosponsor:  
Carl Moyer Program AB 923 Fund 1,178,408

Term: 03/19/07 – 12/31/12  
Total Cost: \$ 1,348,408

SCAQMD awarded Colton Joint Unified School District eight new CNG school buses, while in turn Colton Joint would deliver eight of its newer diesel buses to three other schools willing to crush six older pre-1987 diesel buses and two pre-1977 buses. These schools are Fontana and Coachella Valley Unified School Districts and Sherman American-Indian High School. Colton Joint USD must provide a local match of \$25,000 per bus for the replacement of the pre-1987 buses and \$10,000 per bus for the replacement of the pre-1977 buses. However, due to the school's budget constraints, the SCAQMD approved an additional award of \$170,000 from the Clean Fuels Fund to cover the school's local match.

**07320: Install New CNG Refueling Station in the City of Santa Ana**

Contractor: Orange County Transportation Authority  
SCAQMD Cost-share: \$ 350,000

Cosponsors:  
1309.1 Priority Reserve Fund 180,000  
AES Settlement Fund 470,000  
MSRC/AB 2766 Discretionary Fund 200,000  
Orange County Transportation Authority 4,641,729

Term: 12/21/07 – 12/31/12  
Total Cost: \$ 5,841,729

In May 2006, the Orange County Transportation Authority (OCTA) Board of Directors approved the accelerated procurement and delivery of 249 CNG buses. The CNG refueling station at the Santa Ana Base required significant facility modifications to accommodate the maintenance of CNG vehicles as





**07341: Remote Sensing of Heavy-Duty Engines including Locomotives**

Contractor: Southwest Research Institute SCAQMD Cost-share: \$ 70,000

## Cosponsors:

Union Pacific Railroad 35,000  
Burlington Northern Santa Fe 35,000

Term: 06/29/07 – 12/31/07 Total Cost: \$ 140,000

AB 1222 (Jones) requires that CARB implement a pilot program in consultation with an Advisory Group comprised of recognized experts in the field of remote sensing and locomotive technology, representatives of citizen community groups, SCAQMD, Sacramento Metropolitan AQMD, Union Pacific Railroad, and Burlington Northern Santa Fe Railway to measure the feasibility of using remote sensing device (RSD) technology to determine locomotive exhaust emissions. The project will assist in determining whether the technology can be transferred from light-duty vehicles to heavy heavy-duty engines including locomotives. The pilot program will focus on determining whether RSDs can accurately and reliably determine, with a reasonable level of precision: 1) the levels of NO<sub>x</sub>, PM, and CO emissions from locomotives; 2) whether a locomotive is subject to Tier 0, 1, or 2 federal certification testing; and 3) whether the measured results can be calibrated to determine compliance with applicable federal emission certification levels. AB 1222 requires that the program include data from a sufficient number of locomotives that would be representative of the locomotive fleet operating in Northern and Southern California. CARB and the Advisory Group issued a Request for Qualifications (RFQ) to identify groups capable of performing locomotive exhaust emission tests using Federal Test Procedures (FTP) for locomotives. Four groups responded to the RFQ. The Advisory Group concluded that only Southwest Research Institute (SwRI) met all the necessary qualifications. The Advisory Group also agreed that the certification testing should be performed in California on locomotives identified as operating in California. SwRI is based in San Antonio, Texas, but has a mobile laboratory which it uses to conduct FTP testing in remote locations. The additional cost to transport, staff and make use of the mobile laboratory in California totaled \$140,000. The Advisory Group agreed to the additional expense and the SCAQMD agreed to equally cost-share the additional expense with Burlington Northern Santa Fe and Union Pacific Railroads. Implementation of this phase of the AB 1222 study is scheduled to commence in late January and early February 2008 and will include testing of two locomotives, one a Tier 0 locomotive and the other a Tier 2 locomotive. The intention of the testing is to evaluate the capabilities of RSD technology relative to FTPs over a broad emission range and to perform this testing on locomotives operating in California.

**08033-2: Test Particulate Measurement Device for In-Use Vehicles**

Contractor: California Air Resources Board SCAQMD Cost-share: \$ 125,000

## Cosponsors:

California Air Resources Board 125,000  
Environmental Systems Products 254,514

Term: 06/25/07 – 06/24/10 Total Cost: \$ 504,514

Environmental Systems Products Holdings, Inc. (ESP) has developed an instrument called an Electronic Tailpipe PM Sensor (or ETaPS) that measures PM emissions from exhaust particles as small as 10 nm using a simple electrostatic method. Particles in the exhaust are charged with a corona discharge, and the total electrical charge is then measured. The amount of charge is proportional to

the particle's active surface area and to the PM mass. The instrument is calibrated by correlating these charge measurement with conventional PM test data using filters. Such a low-cost instrument could be used for diesel vehicles as well as stationary-engine measurements. Another part of ESP's business is remote sensing for the detection of high-emitting vehicles and the development of RSD. The overall goal of this project is to correlate ETaPS measurements with RSD and conventional PM filter-based measurements. Potentially, the ETaPS can become a low-cost PM instrument for a diesel vehicle inspection and maintenance (I&M) program. This project will have three tasks. Emissions testing will be conducted on a small number of trucks correlating ETaPS PM measurements with RSD and filter-based measurements. Testing will include the full UDDS, EC13, CBD, and several other driving cycles. Second, a greater number of heavy-duty diesel vehicles will be recruited from truck and bus fleets. Emissions measurements and correlations between the ETaPS-based system and RSD and filter-based system will also be performed on a narrower suite of test driving cycles. Additional information will also be collected on vehicle operating parameters during this task. Finally, the viability of an I&M program based on ETaPS measurements and RSD screening measurements will be evaluated. On-road trucks and buses will be screened by the RSD, and detected gross emitters will be referred to a test station. An abbreviated test cycle will then be performed using the ETaPS using the correlations developed in the first two tasks. It is anticipated that the initial emission cut-points for ETaPS-based I&M program can also be developed.

## ***Emission Control Technologies***

### **07236: Investigate the Role of Lubricating Oil on Particulate Matter Emissions from Vehicles**

Contractor: National Renewable Energy Laboratory	SCAQMD Cost-share: \$	100,000
	Cosponsors:	
	U.S. DOE/NREL	246,887
	California Air Resources Board (pass-through revenue)	100,000
Term: 03/23/07 – 08/31/08	Total Cost: \$	446,887

Engine lubricating oil has been implicated as a significant parent material in the formation of mobile source PM emissions, including recent findings on nanoparticle emissions. This is true of engines burning gasoline, diesel fuel, natural gas, liquid petroleum gas (LPG) and other alternative fuels. As fuels become cleaner (especially with lower sulfur content) and emission control systems become more effective and durable, the contribution of lubricants becomes increasingly significant. Studies have shown that high-emitting engines ("oil burners") are the most toxic in terms of potency per unit mass of emissions. To date, much of the understanding regarding the impact of lubricating oil on particulate matter emissions has been anecdotal and not the subject of a focused and carefully conducted research study. Recognizing this knowledge gap and the potential benefits to air quality and human health, the National Renewable Energy Laboratory (NREL) issued an RFP to investigate the role of lubricating oil on particulate matter emissions from motor vehicles including heavy-duty vehicles, and Southwest Research Institute (SwRI) was selected to perform this investigation. SwRI will perform a preliminary investigation into the role of lubricating oil on engine PM emissions, including emission testing of six different vehicles on chassis dynamometers: two heavy-duty diesel vehicles, a normal- and high-PM emitter; two heavy-duty natural-gas vehicles, a normal- and high-PM emitter; and two light-duty gasoline vehicles, both a normal- and high-PM emitter. These vehicles will be emissions tested with two proposed future lubricating oils. The PM emissions from the testing will be measured, and the PM samples will be speciated by Desert Research Institute to



service for six months to evaluate performance, reliability, and emissions-reduction potential of the SCRT system.

**08161: Demonstrate NO<sub>x</sub> & PM Emissions Control on Construction Equipment**

Contractor: Engine, Fuel & Emissions Engineering, Inc. SCAQMD Cost-share: \$ 135,830

Cosponsors:

Engine, Fuel & Emissions Engineering, Inc. 64,600

Sanitation Districts of Los Angeles County 130,420

Term: 12/31/07 – 02/28/09 Total Cost: \$ 330,850

This project proposes to assess the reliability and emission reduction potential of Engine, Fuel, and Emissions Engineering’s (EF&EE) SCR system on heavy-duty diesel-powered construction equipment operating in the South Coast Air Basin. EF&EE proposes to select two pieces of heavy-duty diesel-powered construction equipment with 3 heavy-duty diesel engines, one of which will be data logged for temperature and vibration level. In addition, EF&EE proposes to establish the baseline NO<sub>x</sub> and PM emissions from each engine using a portable EF&EE’s RAVEM emission measurement system, and conduct an engine dynamometer test on an engine comparable to one of the selected engines in size and application to serve as a baseline engine according to the CARB verification test procedures for off-road engines. The results of this test and in-field data logging will be used to fabricate three SCR systems suitable for heavy-duty construction applications. The fabricated SCR systems will then be installed at the exhaust of each engine, and demonstrated in service for 1100 hours. EF&EE will again conduct on-board measurement of the three engines using the RAVEM portable emission measurement system after the SCR has been conditioned (degreened). After the SCR systems have accumulated 1100 hours, one of the systems will be removed and installed on the baseline engine, and tested on an engine dynamometer according to CARB verification test procedure.

***Electric/Hybrid Technologies***

**99109: Three-Year Lease of One RAV4 Electric Vehicle**

Contractor: Toyota Motor Credit Corporation SCAQMD Cost-share: \$ 7,794

Term: 04/04/99 – 01/01/08 Total Cost: \$ 7,794

The lease of two Toyota RAV4 EV battery electric vehicles is extended for use in the Technology Advancement Advanced Technology Vehicle Demonstration program.



**07265: Demonstrate Electric Tram**

Contractor: Descanso Gardens	SCAQMD Cost-share:	\$	96,000
	Cosponsor:		
	Los Angeles County		25,000
Term: 04/20/07 – 07/19/08	Total Cost:	\$	121,000

In February 2007, the Governing Board approved co-funding to replace the current propane-fueled tram at Descanso Gardens with a zero emission tram for transporting guests through the park as part of their long term vision to become a self-sustaining, alternative-fueled, educational facility. Their existing 45 passenger tram travels 10 miles per day, with a top speed of 10 mph, and operates seven days per week. The low-mileage, stop-and-go, predictable route fits well with the attributes of battery electric vehicles. The proposed electric tram consists of a battery powered electric tug plus three trailers. The tug has a Ballard Ecostar AC drive, Deka gel sealed lead acid batteries, and an onboard Hobart charger. It plugs into a conventional outlet for charging overnight, just like the electric utility carts currently used by Descanso Gardens for groundskeepers. The total cost for this electric tram is approximately \$121,000, with AQMD cost share not to exceed \$96,000 from the Clean Fuels Fund.

**07293: Develop & Demonstrate Electric Tow Tractor for Transportation Containers from Shipping Terminals**

Contractor: Balqon Corporation	SCAQMD Cost-share:	\$	263,500
	Cosponsor:		
	Port of Los Angeles (pass-through revenue)		263,500
Term: 04/27/07 – 05/31/08	Total Cost:	\$	527,000

The Port of Los Angeles (POLA) and SCAQMD have partnered on a joint RFP to demonstrate Class 8 LNG Trucks for the cargo handling port drayage, with anticipated emissions well below their diesel counterparts. However, staff has also discussed even cleaner air technologies that have a potential to further reduce emissions, especially for the over 1 million yearly short trips from the three main marine terminals to the Intermodal Container Transfer Facility (ICTF) located in Wilmington, and POLA nearby warehousing facilities. This project is to develop and demonstrate an electric tow tractor that can replace existing diesel trucks to transport containers from the shipping marine terminals to nearby yards or warehouses, as well as cargo handling and yard hostlers. The proposed tractor is expected to have a fast-charging battery and a range of 40 miles per charge. The design of the tractor will provide sufficient torque and power required to tow up to a 60,000 lb cargo container. This project will result in a demonstration of a Heavy-Duty, Zero- Emission Truck, as well as expedite the placement of advanced technologies and zero emission vehicles in South Coast for on and off-road applications. This project includes a sole-source contract to Balqon Corporation to conduct the above items at a cost not to exceed \$527,500 from the Clean Fuels Fund, with 50% cost share by SCAQMD and POLA.

**08063: Develop & Demonstrate 20 Plug-In Hybrid Electric Vehicles**

Contractor: Quantum Fuel Systems  
Technologies Worldwide,  
Inc.

SCAQMD Cost-share: } 2,095,613

Cosponsor:  
Quantum Fuel Systems 719,653

Term: 12/31/07 – 12/15/14

Total Cost: } 2,815,266

At the November 3, 2006 meeting, the Governing Board approved RFP #P2007-14 to design, engineer, convert, test, certify, demonstrate, and maintain for 60 months 30 plug-in hybrid electric vehicles with supporting infrastructure at up to 15 demonstration sites in the South Coast Air Basin. At the March 2, 2007 meeting, the Governing Board awarded funding to Quantum Fuel Systems Technologies Worldwide, Inc. to convert 20 new Ford Escape Hybrid vehicles to plug-in hybrid electric vehicles using advanced lithium-ion battery systems and controls. The vehicles plug into a conventional outlet for charging overnight, and can be refueled with gasoline for longer trips. The total cost for this project is \$2,815,266, with SCAQMD cost share not to exceed \$2,095,613 from the Clean Fuels Fund.

**08067: Demonstrate Hydraulic-Hybrid Shuttle Bus**

Contractor: Calstart

SCAQMD Cost-share: \$ 250,000

Cosponsors:  
Eaton Corporation 300,000  
Complete Coach Works 327,500  
Riverside Transit Agency 42,500  
Federal Transit Administration 290,000

Term: 10/30/07 – 03/31/10

Total Cost: \$ 1,210,000

Hybrid technologies represent a method to further reduce emissions from existing low emission engines as well as to reduce fuel consumption and the generation of greenhouse gases. Hybrid technologies use a combination of energy sources to propel vehicles, generally an internal combustion engine and another source. Vehicle manufacturers have commercialized hybrid-electric passenger cars, trucks and buses. During braking, these hybrid-electric vehicles capture energy normally lost as heat in the braking system; an electric motor/alternator is used to slow the vehicle and generate electricity which is stored in a battery or capacitor pack. During propulsion, the stored electricity is used to power the electric motor and help propel the vehicle. Emissions, fuel consumption and carbon dioxide emissions can be reduced by up to 25 percent. Wear and tear on the braking system is also reduced, further lowering operating costs. Non-electric, mechanical hybrid systems also have been under development in the last few years. One such technology is the hydraulic-hybrid system, which uses a special hydraulic pump/motor installed in the vehicle drivetrain, usually between the transmission and drive shaft. During braking, the pump/motor slows the vehicle by pumping hydraulic fluid and compressing gas in a pressure tank. During propulsion, the process is reversed, pressure is released, and the hydraulic pump/motor helps propel the vehicle. As with hybrid-electric systems, microprocessors control the energy collection and release based on the vehicle speed, brake pedal position, throttle position, and other factors. CALSTART, in association with Eaton Corporation, Complete Coach Works and Riverside Transit Agency (RTA), has proposed to develop and demonstrate a hydraulic-hybrid system on a shuttle bus. The advantages are lower emissions, lower fuel consumption, and reduced brake maintenance.

## **Engine Technologies**

### **07306: Develop, Demonstrate & Certify Heavy-Duty Natural Gas Engine Meeting 2010 Emission Standards**

Contractor: Emissions Solutions, Inc. SCAQMD Cost-share: \$ 400,000

Cosponsors:

Southern California Gas 300,000

Clean Energy 100,000

Emission Solutions, Inc. 400,000

Term: 06/28/07 – 07/31/08

Total Cost: \$ 1,200,000

Emission Solutions proposes to develop, demonstrate, and certify a 7.6L heavy-duty natural gas engine that could be used in both the repower of existing diesel engines as well as in new vehicles that meet the 2010 heavy-duty engine NO<sub>x</sub> standard. In order to meet the 2010 NO<sub>x</sub> emission standard, Emission Solutions will consider a number of emission control techniques that include cooled EGR, variable geometry turbo-charging, exhaust gas aftertreatment using a three-way catalytic converter, and development of an engine controller that manages all engine control functions. In addition, Emission Solutions proposes to negotiate and execute agreements with interested fleets for the purpose of monitoring and verifying the performance of this engine model in various fleet applications. It is expected that the natural gas engine model developed from this project will be primarily used in school bus applications.

## **Mobile Fuel Cell Technologies**

### **04126: Lease of One Additional Honda Fuel Cell Electric Vehicle**

Contractor: American Honda Motor Co., Inc. SCAQMD Cost-share: \$ 10,825

Term: 06/22/04 – 05/23/08

Total Cost: \$ 10,825

The lease of two Honda fuel cell passenger vehicles is extended for use in the Technology Advancement Advanced Technology Vehicle Demonstration program.

### **07356: Upgrade & Demonstrate Fuel Cell Bus**

Contractor: ISE Research Corporation SCAQMD Cost-share: \$ 325,000

Cosponsors:

Calstart 130,000

California Air Resources Board 640,000

SunLine Operations 60,000

SunLine Transit Agency 130,000

Term: 11/02/07 – 08/31/09

Total Cost: \$ 1,285,000

In May 2001, the Board approved a hybrid electric fuel cell bus demonstration project, which was completed in 2004. This project successfully demonstrated a fuel cell bus with double the energy

efficiency of a comparable existing natural gas bus, with equivalent reliability. The bus was retired in late 2004 due to the expiration of the fuel cell warranty. In April 2007, the Board approved a new demonstration project involving an upgrade to the fuel cell stack on the existing bus. ISE Corporation, the original project proponent, is proposing to upgrade the existing bus with a new 75 kw fuel cell module manufactured by Ballard, which includes a 12,000 hour or five year warranty period, whichever comes first. This is a six time improvement in the warranty compared to fuel cell buses currently in demonstration. Additionally, the existing lead acid batteries will be replaced with advanced lithium ion batteries that reduce weight while providing more energy density. Lastly, the 3,600 psi hydrogen storage will be replaced with a 5,000 psi rated hydrogen storage system, which is expected to provide a greater range. Upon completion of the upgrade and testing phase, the bus will provide revenue service as a part of SunLine’s transit fleet operations. ISE Corporation will provide bus transport, on-site training and field support as needed.

### ***Hydrogen Technologies and Infrastructure***

#### **Purchase Order: Refurbish Hydrogen Refueling Station at SCAQMD Headquarters in Diamond Bar**

Contractor: Hydrogenics Corporation	SCAQMD Cost-share:	\$	43,000
Term: 06/12/07 – 07/31/07	Total Cost:	\$	43,000

The SCAQMD, in partnership with Hydrogenics Corporation (formerly Stuart Energy Systems) installed a hydrogen generation and fueling station at SCAQMD Headquarters in Diamond Bar. This station uses electrolysis of water to produce the hydrogen and includes the capability to produce backup electrical power using a hydrogen-powered internal combustion engine. This station has become a vital location as part of the California Hydrogen Highway network. Unfortunately, a failure of one of the two cell stacks occurred, creating stress on the remaining stack and components; the manufacturer strongly recommended replacement of both cells. In June 2007, the SCAQMD Board approved refurbishment of two new cell stacks and two additional spare stacks. A purchase order was approved up to \$43,000 for Hydrogenics to refurbish the facility accordingly. The work was performed during early summer and the station resumed operation.

### ***Health Impacts Studies***

#### **07181: Physical, Chemical & Toxicological Assessment of the Semi-Volatile & Non-Volatile Fraction of PM**

Contractor: California Air Resources Board	SCAQMD Cost-share:	\$	338,975
	Cosponsor:		
	California Air Resources Board		338,975
Term: 01/17/07 – 04/01/10	Total Cost:	\$	677,950

Current emissions control technologies for PM effectively remove the non-volatile, or solid, fraction of emissions. However, they may not be as effective in removing the volatile precursors for ultrafine particles. In fact, some studies have indicated that the removal of the solid portion of emissions can increase the concentration of the volatile fraction and enhance the formation of ultrafine particles from condensation of the more volatile fraction. There is growing evidence that ultrafine particles

may have a higher toxicity than larger particles. This project proposes to assess the physical, chemical, and toxicological properties of semi-volatile and non-volatile fractions of PM from heavy- and light-duty vehicles. The semi-volatile emissions can condense and form high numbers of ultrafine particles. Both fine and ultrafine PM emissions from conventional and advanced technology vehicles will be assessed. The project will be conducted collaboratively by CARB, University of Southern California (USC), and University of California Los Angeles (UCLA). CARB will test the vehicles on a dynamometer and characterize the emissions, and USC and UCLA will assess the chemical and toxicological properties of the emissions. Concentrated fine and ultrafine particles emitted from different engine and vehicle configurations will be collected, and their toxicity tested. Samples will be collected from several types of vehicles, including conventional heavy-duty diesel, a heavy-duty diesel vehicle equipped with a particulate filter and fueled with low-sulfur diesel fuel, a heavy-duty CNG vehicle, and a heavy-duty CNG vehicle equipped with oxidation catalyst emission controls.

**07196: Environmental Justice Saturation Monitoring of Selected Pollutants in Wilmington, CA**

Contractor: California Air Resources Board	SCAQMD Cost-share: \$	100,000
	Cosponsor:	
	California Air Resources Board	300,000
Term: 01/17/07 – 12/31/08	Total Cost: \$	400,000

Under this project, Desert Research Institute will measure air quality at several sites over a several-week period to determine if there are concentration gradients of pollutants impacted by stationary, mobile and area sources. This will provide data on exposures at a much higher spatial resolution at the community level than past air quality studies have provided. This project is being done as part of a larger effort by CARB to integrate environmental justice concerns, including cumulative impacts and socioeconomic vulnerability, in analyses of air pollution health impacts. The project will use passive sampling techniques for gaseous pollutants such as NO<sub>x</sub> and organics, and will use portable mini samplers for particulates. The first part of the research will be to validate the use and results of these methods as compared to traditional air quality measurements. The second part will be to deploy the measurement devices at up to 30 sites in the community and collect data over several weeks during different seasons. The data is expected to result in an improved understanding of actual exposure levels in a community with multiple air pollution sources.

**07359: Study on Combustion Exhaust and Respiratory Health of Port Community Children**

Contractor: University of Southern California	SCAQMD Cost-share: \$	489,300
	Cosponsor:	
	National Institutes of Environmental Health Sciences	2,500,000
Term: 12/14/07 – 08/31/08	Total Cost: \$	2,989,300

Over the past several years, regulators, scientists, and public health officials have become increasingly aware of long-term adverse consequences of ambient air pollution exposure on the lung development and respiratory health of young children. Emissions related to transport of goods through the ports of San Pedro Bay have led to concerns among community residents and public health researchers that such emissions may be increasing the risk of asthma in children living and

going to schools in communities near port transportation corridors. While numerous public health and educational professionals, as well as community members in the area, have impressions that children's asthma prevalence may be much higher among residents near the ports compared to other areas of the South Coast, no objective information is available to either confirm or refute these conclusions. This study, which is an add-on to a study conducted by the National Institutes of Environmental Health (NIEHS), will focus on combustion exhaust exposure gradients resulting from substantial and increasing transport of commercial goods by truck and rail, across communities whose boundaries encompass major transportation corridors. To address these issues, USC proposes to augment their current investigation of children's respiratory health in Long Beach and other Southern California communities by recruiting an additional 3,000 schoolchildren in the communities of San Pedro, Wilmington, and West Long Beach. Incident and prevalent asthma (in kindergarten and fourth-grade students, respectively) will be assessed. Results from this study will provide objective data on the prevalence of asthma in port community children. From the public health and regulatory perspectives, direct information about the respiratory health status of communities impacted by goods movement activities will provide objective data where there currently is a vacuum of available information. This information can be used to determine the health benefits of using alternate and advanced technologies to reduce diesel emissions.

**08033-4: Spatiotemporal Analysis of Air Pollution and Mortality in California Based on the American Cancer Society Cohort**

Contractor: California Air Resources Board	SCAQMD Cost-share: \$ 374,988
	Cosponsor:
	California Air Resources Board 374,988
Term: 06/25/07 – 06/24/10	Total Cost: \$ 749,976

This project to be conducted by the University of California at Berkeley is to perform an analysis of mortality and its relation to air pollutant levels in a cohort of individuals from the American Cancer Society (ACS) cohort. This is a national cohort recruited by the ACS for a long-term study and includes over 95,000 residents in California. Information of various health risk factors, dietary, lifestyle, demographic, occupational and educational influences has also been collected for this cohort. The proposed project will analyze deaths in this group between 1982 and 2000 and the levels of air pollution estimated from available monitoring data at the residence of each member. The researchers will use a geospatial interpolation method previously developed to estimate the pollutant levels. This is an innovative method for large scale studies, and is thought to give a more accurate measure of pollutant exposure than using a central city monitor or average of several monitors in a geographic area. Previous work by the researchers on a southern California cohort found higher health effects from exposure to particulate matter than studies using national cohorts. The proposed study will use a much larger number of study subjects residing in major cities throughout the state and will provide for a larger statistical power for the analyses.



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 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 CaFCP administration. In 2007 the SCAQMD Board contributed \$83,800 for membership and up to \$50,000, along with staffing space at SCAQMD Headquarters, to provide support for the CaFCP Regional Coordinator.

**05127: Technical Assistance for Development, Outreach and Commercialization of Hydrogen & Fuel Cell Applications**

Contractor: Protium Energy Technologies	SCAQMD Cost-share:	\$	20,000
Term: 03/14/05 – 03/31/08	Total Cost:	\$	20,000

Fuel cells are emerging as a leading alternative to the internal combustion engines in vehicle, marine and stationary distributed energy applications. The SCAQMD supports development of fuel cell technologies and is currently sponsoring programs focused on advancement of specific fuel cell systems and determining fuel quality issues for fuel cells. The SCAQMD is working with government and industries to further commercialize mobile and stationary fuel cells in stationary and mobile applications. In 2007 an additional \$20,000 was allocated to Protium Energy Technologies to provide continued expertise and assistance in the development and commercialization of hydrogen vehicles to be used in the marketplace.

**06061: Consulting Services in Preparation of Mobile Source Emissions Element of 2007 AQMP**

Contractor: Saint Malo Solutions	SCAQMD Cost-share:	\$	40,000
Term: 05/17/06 – 03/31/08	Total Cost:	\$	40,000

The mobile source emissions inventory is a critical component in the development of the 2007 AQMP Revision. Revisions to the mobile source emissions inventory have been made over the last several years, and continue to be made, to incorporate the best available knowledge. It is essential that the latest technical data on in-use emission factors be used in its formulation. New data is becoming available with respect to On-Board Diagnostics II, in-use performance, vehicle demographics, vehicle inspection and maintenance, fuel solubility and evaporation effects, brand loyalty to various types of fuels, off-road emission factors, and other aspects of the mobile source emissions inventory. A full understanding of market trends, recent certification data, engineering and technology trends, as well as inventory uncertainties, is central to properly evaluating the impact of control strategies relative to the SCAQMD baseline inventory and emissions forecasts. It is important to understand the nuances in assumptions which influence emission inventory estimates, which in turn affect air quality modeling scenarios, and ultimately control measure design and analysis. Mr. Mark Carlock, Saint Malo Solutions' principal, is a nationally recognized expert on emissions inventory development and validation. He was formerly the Branch Chief for CARB's Mobile Source Analysis Branch, with direct responsibility for developing and updating the EMFAC emissions inventory used in the development of the 2007 AQMP. In 2007 an additional \$40,000 was allocated to Saint Malo Solutions to provide continued technical assistance from Mr. Carlock.



**07059: Technical Assistance Related to Air Quality Impacts of Regional Goods**

Contractor: Dowling Associates, Inc. SCAQMD Cost-share: \$ 10,000

Term: 12/19/06 – 11/30/08 Total Cost: \$ 10,000

As a result of the significant growth in regional goods movement, pollutant emissions and air quality impacts around the marine ports and distribution centers are increasingly significant and need to be addressed expeditiously. Dowling Associates, Inc.'s team will consist of experts in the area of terminal operations, marine vessel operations, control strategy development, and truck operations. Under this contract, Dowling Associates, Inc.'s team will also provide technical assistance and expert consultation regarding the vehicle miles traveled (VMT) estimates in the latest CARB EMFAC model. In 2007, an additional \$15,000 was allocated to Dowling Associates to provide continued technical assistance.

**07130: Technical Assistance with CNG Technology**

Contractor: Burnett & Burnette SCAQMD Cost-share: \$ 40,000

Term: 01/17/07 – 12/31/08 Total Cost: \$ 40,000

On May 5, 2006, the Board approved release of an RFP to solicit proposals to provide technical assistance and public outreach support for advanced, low- and zero-emission mobile and stationary source pollution control technologies. Eleven proposals were received and reviewed. Burnett and Burnette has worked extensively with vehicle manufacturers and conversion companies in the penetration of CNG vehicles and as a result of his expertise, Mr. Herb Burnett was selected to provide technical assistance with CNG engine technology and the development and commercialization of the CNG infrastructure.

**07185: Technical Assistance for Development, Outreach & Commercialization of Advanced Low-Emission Vehicle Technologies**

Contractor: Joseph C. Calhoun, P.E., SCAQMD Cost-share: \$ 20,000  
Inc.

Term: 01/29/07 – 01/31/08 Total Cost: \$ 20,000

The major light-duty vehicle manufacturers have improved the natural gas, hydrogen, and electric vehicles used in the marketplace. Due to fluctuating gasoline prices, a more available fueling infrastructure network, and vehicle reliability and durability, the public and fleet managers are now more receptive to alternative fuel technologies. Hybrid electric technologies in both light- and heavy-duty applications are developing as a major contribution to achieve federal and state ambient air quality standards in the Basin. Hybrid electric technology can be coupled with natural gas engines, microturbines, and fuel cells as well as gasoline and diesel engines. To promote, fund, manage, and expedite the development and demonstration of such advanced technology projects, Mr. Calhoun will work with SCAQMD staff to provide expertise in alternative fuels for light- and heavy-duty vehicles and outreach for dissemination and commercialization of new technologies.

**07241: Technical Assistance for Cellulosic Ethanol Forum & Roundtable**

Contractor: Charles Wyman, Ph.D. SCAQMD Cost-share: \$ 7,300  
Term: 02/24/07 – 07/31/07 Total Cost: \$ 7,300

Mobile sources in the South Coast Air Basin are substantial contributors of air pollution and toxic risk affecting the residents of the South Coast Air Basin. Over 95 percent of the fuel used in mobile sources is based on petroleum, such as gasoline and diesel. Alternative fuels, such as ethanol, can reduce this dependency on petroleum and also enable this agency to meet its targeted air quality goals. Current production of corn-based ethanol is ultimately limited by a number of factors. To be sustainable in the long-term, ethanol needs to be produced from forest and agricultural residues such as corn stalks and rice stalks, and other plant materials including grasses and wood grown for this purpose. Dr. Charles Wyman, professor at University of California, Riverside, was retained by the SCAQMD to host a one-day technology forum to examine current and future technologies that could increase production of ethanol from biomass sources of waste cellulose. The morning consisted of formal presentations by a panel of national technical experts on the production of cellulosic ethanol. In the afternoon, these panelists participated in a round-table discussion and took questions from the public. Presentations of the panelists are posted on the AQMD's Technology Forum/Roundtable Web page: <http://www.aqmd.gov/tao/ConferencesWorkshops/techforum.htm>.

**07247: Technical Assistance with Low-Emission and Alternative Fuels Technologies**

Contractor: TIAX LLC SCAQMD Cost-share: \$ 50,000  
Term: 03/19/07 – 12/31/08 Total Cost: \$ 50,000

Due to the constant and rapid changes in technologies, and the sheer breadth of the potential projects, TAO staff requires input from experts and practitioners in the field to aid in selecting and establishing projects under the Clean Fuels Program. TIAX, LLC will provide technical assistance for low-emission and alternative fuels technologies such as low- and zero-emission mobile source technologies, emissions testing, and alternative fuel vehicles. TIAX, LLC also provides staff knowledgeable in heavy-duty vehicle control technologies; off-road vehicles and equipment; and state and federal programs, policies, and regulations regarding off-road and alternative vehicles.

**07257: Technical Assistance for Forum & Roundtable on Cellulosic Ethanol**

Contractor: Michael Studer, Ph.D. SCAQMD Cost-share: \$ 1,000  
Term: 04/11/07 – 07/31/07 Total Cost: \$ 1,000

Dr. Michael Studer was retained to attend the Cellulosic Ethanol Forum and Technical Roundtable to be held at the SCAQMD Headquarters on February 15, 2007. Dr. Studer, in conjunction with Dr. Charles Wyman, attend the Forum & Roundtable and took notes to summarize the meeting, the purpose of which was to assess the status, future, challenges, and economics of introducing cellulosic ethanol as a transportation fuel in the South Coast Basin. The findings of this meeting will help SCAQMD determine the appropriate research plan to adopt regulations and/or provide incentives for the development of this fuel in leverage with state and federal programs.

**07262: Technical Assistance for Smog Check Technology Forum & Roundtable**

Contractor: Judith Lamare SCAQMD Cost-share: \$ 12,000

Term: 03/16/07 – 07/31/07 Total Cost: \$ 12,000

In March 2007, the SCAQMD convened a technical forum on smog check to look for significant new reductions from in-use light duty vehicles beyond the proposal by the CARB for the 2007 State Implementation Plan (SIP). In order to facilitate discussions among a panel of experts, the Executive Officer approved a level of effort contract with Dr. Judith Lamare who earned her Ph.D. in 1973 from the Political Science Department at University of California, Los Angeles. She joined the Senate Office Research of the California Legislature in 1977 to work on transportation policy. She was the acting chair of the California Vehicle Inspection and Maintenance Review Committee and Co-Chairs of the California Environmental Dialogue's "Clean Air Dialogue" working group. She is a policy advisor for the Cleaner Air Partnership and the Sacramento Air District. The technical forum was conducted on March 21, 2007, with an expert panel consisting of representatives from the CARB, Bureau of Automotive Repair, Saint Malo Solution Consultant, Environmental Systems Products, and University of California at Riverside. Dr. Lamare led the discussion on ways to improve California's Smog Check Program and wrote a summary of the discussion and presentations made.

**07314: Technical Assistance with Advanced Heavy-Duty and Off-Road Technologies**

Contractor: Engine, Fuel & Emissions SCAQMD Cost-share: \$ 60,000  
Engineering, Inc.

Term: 06/25/07 – 12/31/09 Total Cost: \$ 60,000

Mr. Christopher Weaver, the firm's president, brings over 22 years of experience in the areas of internal combustion engine technology, fuels, combustion, and emission controls. Mr. Weaver will provide expertise with the measurement and control of fine particulate emissions from diesel vehicles; emission measurements and control technology for trucks, buses, railway locomotives, and other heavy-duty diesel vehicles; natural gas, and other "clean" fuels for vehicles. Mr. Weaver also has experience and can provide assistance with environmental economics, cost-effectiveness and policy analyses.

**07342: Technical Assistance for Mobile Source Technologies**

Contractor: Douglas R. Lawson SCAQMD Cost-share: \$ 15,000

Term: 06/21/07 – 08/31/08 Total Cost: \$ 15,000

CARB's Remote Sensing Pilot Study Report lays out a detailed evaluation of the feasibility of utilizing remote sensing technology to augment the existing Smog Check Program. The commitment to conduct this remote sensing feasibility study originated from a State Implementation Plan (SIP) commitment made in a 2000 SIP submittal. The Smog Check Program is a cornerstone of our mobile source control strategy and many believe that additional emission reductions can be achieved by incorporating this component in the existing program. Recent data from CARB shows that emissions from cars, trucks and other vehicles, particularly older cars, are significantly higher than previously estimated. To reach federal health standards, however, additional control measures will have to be developed, implemented and enforced in the area of better in-use controls of existing fleets. Dr. Lawson will lend his technical expertise as SCAQMD begins to evaluate technologies needed to meet

future mobile source emission standards and potential SCAQMD rules, including the possible amendment to the California Smog Check Program. Dr. Lawson is a respected expert on air pollution, specifically related to mobile source pollution, with 29 years of professional experience. His experience and expertise in this field span the spectrum of participation on the Inspection and Maintenance Program for the State of Colorado and performing several remote sensing studies while employed at Desert Research Institute and CARB. Dr. Lawson is currently the Principal Scientist at the NREL in Golden, Colorado, where he is the director of the U.S. Department of Energy's Environmental Science & Health Effects Program.

**Direct: Co-Host CAPCOA's The Future is Green Conference & Expo in September 2008**

Contractor: California Air Pollution Control Officers' Association (CAPCOA)	SCAQMD Cost-share:	\$	50,000
Cosponsors:			0
Bay Area Air Quality Management District			50,000
Sacramento Metro Air Quality Management District			10,000
Placer County Air Pollution Control District			5,000
	Various Sponsors		385,000
Term: 09/18/07 – 09/18/08	Total Cost:	\$	500,000

Air pollution, global warming, and petroleum dependency are concerns shared by everyone from government to business to the public. Development and commercialization of clean air technologies and innovations are key components toward addressing these issues and ensuring the future is green for us and our children. CAPCOA asked the SCAQMD to co-host their upcoming The Future is Green Conference & Expo to be conducted on September 14-16, 2008, at the Long Beach Convention Center. Panel sessions will be presented on clean fuel technologies, clean fleet vehicles and equipment, green building design and energy efficiency, renewable power generation, green transportation systems technologies, green consumer products, and green agricultural equipment and operations. Workshops for science students and teachers will also be conducted, and the expo will consist of approximately 100 exhibits featuring green technologies and products from major auto companies to eco-friendly products. The public will also be invited to attend the expo. The SCAQMD is also providing in-kind services for its staff to coordinate the majority of the logistics of the event.

**Transfer: Participate in California Natural Gas Vehicle Partnership**

Contractor: California Natural Gas Vehicle Partnership	SCAQMD Cost-share:	\$	25,000
Cosponsors:			
	Various partners		225,000
Term: 02/02/07 – 02/02/08	Total Cost:	\$	250,000

The California Natural Gas Vehicle Partnership was formed to accelerate the development of advanced natural gas vehicle technologies, to provide a benchmark for lowering emissions from petroleum-based engines, and to provide a pathway to future fuel cell use in the next two decades. The SCAQMD spearheaded the formation of this strategic alliance, which comprises state and federal

air quality, transportation and energy agencies, vehicle and engine manufacturers, fuel providers, transit and refuse hauler organizations. Partnership Steering Committee members contribute monies to fund specific projects intended to achieve the goal of the Partnership. In February 2007, the SCAQMD Board approved \$25,000 for the SCAQMD's participation on the Steering Committee.

**Transfer: Return Funds Received from LADWP Settlement Fund in CY 2003 to Re-allocate to City of Los Angeles Million Trees Initiative**

Contractor: City of Los Angeles SCAQMD Cost-share: \$ 933,050

Term: 09/07/07 – 09/07/07 Total Cost: \$ 933,050

The Center for Urban Forest Research (CURF) reported in a recent study that trees can remove significant amounts of PM, CO<sub>2</sub>, ozone precursors, and other gaseous contaminants from the atmosphere. The CURF is joining efforts with cities and local communities in California to apply, on a broad scale, the lessons learned from this study. In support of this effort, the City of Los Angeles has initiated a program to plant one million low-VOC emitting trees within the City's jurisdiction. Funds had previously been transferred into the Clean Fuels Fund as a result of the LADWP settlement, but the project they were intended for was unable to go forward. Consequently, this action is to transfer the funds back to their original special fund and then execute an interagency agreement with the City of Los Angeles to co-fund the Million Trees Initiative.

**Varies: Co-Sponsorships of Conferences, Workshops and Events, plus Memberships**

Contractor: Various Contractors SCAQMD Cost-share: \$204,723

Cosponsors:

Various

Term: Various Total Cost: \$1,599,250

The SCAQMD regularly participates in and hosts or cosponsors conferences, workshops and events. These funds provide support for 18 events during 2007, plus 3 business council or association memberships. The 18 conferences, workshops and events are as follows: 13th Alternative Fuels & Vehicles National Conference & Expo; 8th Annual Western Riverside Council of Governments' Advancing the Choice Event; The Clean Ships: Advanced Technology for Clean Air Conference; 17th Annual CRC On-Road Vehicle Emissions Workshop; California Climate Action Registry's 5th Annual Conference; The First Clean Air Car Show & Film Festival; Environmental & Medical Nanotechnology Innovations Conference; Southern California Clean Vehicle Technology Expo 2007; Blue Sky Awards 2007; EVS-23 "Sustainability: The Future of Transportation" Electric Vehicle Symposium; Wet Cleaning Seminar; Western Riverside Council of Governments' Car Care for Clean Air Events; Alternative Fuels Demo Day Event; 2007 Haagen-Smit Symposium; Santa Monica Alternative Energy & Transportation Expo; Asian American Environ Symposium at Cal Poly Pomona; and National Urban Freight Conference. The three memberships for 2007 were for participation in the California Hydrogen Business Council, California Environmental Business Council, and U.S. Fuel Cell Council Association.



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## PROGRESS IN 2007

### Key Projects Completed

A large number of emission sources contribute to the air quality problems in Southern California. 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 co-funded 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 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 their infrastructures. Stationary source projects have included a wide array of advanced low NO<sub>x</sub> technologies and clean energy alternatives, such as fuel cells, solar power, and other renewable energy systems.

Table 5 provides a list of projects completed in 2007; 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.

#### **Oxidation Catalysts to Reduce CNG Heavy-Duty Vehicle Emissions**

The efforts of public agencies and private industry have resulted in an increased number of vehicles now powered by CNG engines. The vast majority of older heavy-duty CNG engines are not equipped with exhaust emissions control technologies. Since CNG engines are inherently cleaner than their conventional-fueled counterparts, previous studies of exhaust emissions from CNG-fueled transit buses have shown that oxidation catalysts can reduce non-methane hydrocarbons emissions (including toxic hydrocarbons such as formaldehyde and benzene) by at least 85 percent and also reduce CO and PM emissions. Based on these studies and the proven effectiveness and availability of catalytic technologies, oxidation catalysts offer a unique opportunity for even greater emission reductions from CNG buses.

The goal of the project completed by Engine Control Systems Limited (ECS) was to optimize and demonstrate oxidation catalyst technology to further reduce exhaust emissions from heavy-duty CNG engines, specifically 2002 and other Detroit Diesel (DDC) Series 50G CNG engines. The emissions demonstration was planned over the Orange County Transit Agency (OCTA) emissions test cycle and 8-mode steady-state test conditions.

In this project, a DDC Series 50G CNG urban bus engine was tested over a steady-state test procedure on an engine dynamometer, while the engine was independently equipped with three oxidation catalysts. One of the catalysts was the same formulation used on a limited number of OEM CNG engines, and the other two formulations were optimized for maximum reduction of benzene, formaldehyde, PM, and non-methane hydrocarbon emissions. An improved exhaust sensor was installed to protect the catalyst from potential rich fuel excursions. The results of the engine dynamometer test and in-field data logging of exhaust temperatures and pressures from test buses

were used to select and optimize at least two oxidation catalysts suitable for CNG urban bus applications. The oxidation catalysts were then packaged and installed on the exhaust of a Neoplan bus operated by Metropolitan Transportation Authority (MTA) and a 2002 model year bus operated by Riverside Transit Authority (RTA), and the buses were operated over a 12-month demonstration program. At the end of the demonstration, the two buses were evaluated on the West Virginia University (WVU) portable chassis dynamometer over OCTA emissions test cycle and selected steady-state test conditions.



**Figure 8: WVU Portable Chassis Dynamometer**



**Figure 9: Prototype Engine at Environmental Canada**

The table below reports the oxidation catalyst performance on regulated and unregulated emissions from the upgraded 2002 urban bus operated by RTA.

**Table 4: Emissions Change Observed with Oxidation Catalysts**

<u>Emission</u>	<u>Percent Change</u>
Carbon Monoxide (CO)	-100%
Nitrogen Oxides (NO <sub>x</sub> )*	+19%
Total Hydrocarbons (THC)	-62%
Particulate Matter Mass (PM)	-100%
Carbon Dioxide (CO <sub>2</sub> )	-2.5%
Miles/gallon equivalent	+4.5%
Carbonyls	-96%
Polyaromatic Hydrocarbons (PAH)	Reduced to non-detectable levels
Semi-volatile PAH	-56%
Gas Phase PAH	-46%
Nitro PAH	-60%
VOC's	-85%
Particles (hot catalyst)	Reduced by an order of magnitude
Particle (cold catalyst)	No effect



After one year of durability demonstration, regulated and unregulated toxic and particle emissions were greatly reduced. The only exception was found to be NO<sub>x</sub> emissions. The noted increase in NO<sub>x</sub> emissions and fuel economy is believed to be an artifact of the ECM sensor signals which were affected by the oxidation catalytic converter muffler and exhaust temperature sensor. Adjustments to the sensor would provide comparable NO<sub>x</sub> emissions and fuel economy values with and without the oxidation catalytic converter.

This study showed that regulated CO, THC, NMHC, PM and unregulated emissions of toxic compounds and particles of older in-use heavy-duty CNG-fueled engines can be significantly reduced by upgrading with oxidation catalysts and revised engine software.

### Plug-in Hybrid Electric Vehicle with Lithium Polymer Batteries

Plug-in hybrid electric vehicles are hybrid vehicles with larger batteries that can be recharged to enable longer distances traveled without engine operation and higher overall fuel economy. For longer trips, they can also be refueled by gasoline or other alternative fuel, depending on design. Reducing the number of engine cold starts, increasing zero emission distance traveled, and increasing fuel economy provide important emission reductions, especially in disproportionately impacted urban areas.

AC Propulsion originally developed and demonstrated a plug-in hybrid electric passenger vehicle in 2003 with contributions from Volkswagen, SCAQMD, CARB, and NREL. This project demonstrated the advances in battery technology by upgrading the original Panasonic valve-regulated lead acid batteries to Kokam lithium batteries to provide improved performance by reducing weight, increasing power, and increasing energy storage. After 6,000 miles of operation, the Kokam lithium batteries by LG Chem improved vehicle acceleration, extended range, improved fuel efficiency, reduced gasoline consumption, and reduced cold starts.



Figure 10: Jetta Demo Vehicle

	PHEV Li	PHEV PbA	ICEV Base
Battery lbs	280	725	NA
Vehicle lbs	3235	3680	2885
EV range mi	50	30	0
EV eff Wh/mi	190	210	NA
City mpg gas	120	58	23
Hiway mpg gas	34	31	29
0-60 secs	8.0 sec	8.5 sec	12.0 sec
Cold starts/week	2 (est)	8 (est)	16 (est)

Figure 11: Performance & Emissions Comparison

The Volt, proposed by General Motors for 2010 production, and the Jetta PHEV, originally developed in 2003 share similar architecture and functionality. Both are series hybrids that use internal combustion engines only for electricity generation. Both use front-wheel drive for propulsion, and low, centrally mounted battery packs of about 14 kW capacities. Both can plug in to the grid and rely exclusively on the battery for all driving until the battery is discharged. Several automakers are evaluating a variety of lithium battery technologies to determine whether they can meet automotive requirements for cost, safety, and durability in production PHEVs. LG Chem is one of two lithium battery suppliers developing batteries for the Volt.

This project demonstrated one of several potential PHEV configurations and the progress made recently in the key enabling battery technology. Demonstrations such as this raise the visibility of promising technologies, pushing major automakers to compete for new clean vehicle technology leadership, and help prepare component suppliers to meet high expectations for new product development. Commercialization and introduction of PHEVs are important control strategies in the AQMP.

### **On-Board Diagnostic II (OBDII) System for CNG Natural Gas Vehicles**

This project targeted the development of the OBDII system and engine calibrations for Baytech Corporation's GM CNG vans and van-derivatives. In recent years, CARB granted flexibility to small-volume manufacturers of alternative fuel vehicles such as Baytech due to the significant hurdles to fully comply with California OBDII requirements. For 2005 models, CARB granted Baytech OBDII approval with certain deficiencies. However, for 2006 and later models full compliance was required. This project assisted Baytech to achieve full OBDII compliance.

Baytech's Sequential MPFI system for CNG consists of an injector block assembly and gas distribution system from each injector to the respective cylinder, injector driver module, coalescing filter, pressure regulator, and electric shut-off valve. Baytech's CNG engine calibration software is implemented in the OEM Powertrain Control Module (PCM), which controls the air-fuel ratio to stoichiometric (as modified to account for special operating conditions) using oxygen sensors and closed loop control.



**Figure 12: Baytech's CNG Injector Block Installed on GM 6.0L Van**



**Figure 13: 2007 Baytech CNG Savannah Van**

Limited space above the van's engine requires using a "split" injector block, with four injectors on each side of the engine. Baytech's CNG system fully utilizes the original GM OBDII system, which is designed to monitor and detect problems with the vehicle emissions system.

During this project, Baytech developed new engine calibrations and performed emission testing to demonstrate OBDII compliance with their newest CNG system for 2006 model GM full-size vans and cut-away vans. This involved emission testing with both new and aged components such as fuel injectors, catalytic converters, and oxygen sensors. Baytech also produced a detailed OBDII compliance document for CARB certification. Finally, Baytech developed streamlined OBDII procedures which can be used in future years for alternative OBDII certification.

Baytech received OBDII approval from CARB for a set of CNG light-duty vehicles for 2006 and 2007 model years, including the full-size van and van cut-away models, which were certified to

California SULEV emission standards. Baytech also conducted an analysis comparing the emissions test results under malfunction conditions using 120K-mile aged components and 4K-mile aged components, with the objective of showing how streamlined methods potentially could be used to demonstrate OBDII compliance for future model years. The potential streamlined methods use worst-case Baytech-derived deterioration factors, based on 4K- and 120K-mile aged component testing, to predict the end-of-life emissions when testing emission malfunctions with 4K-mile aged components.

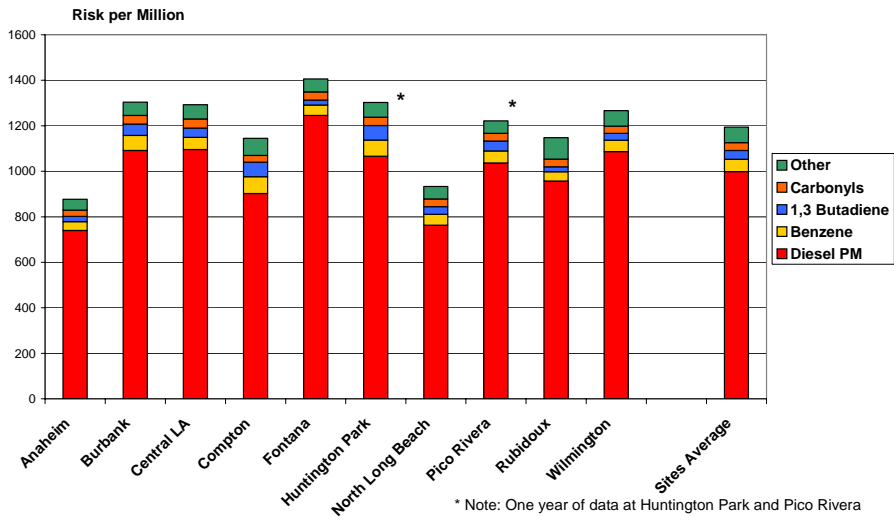
This project demonstrated to CARB that properly engineered natural gas vehicles (NGVs) can be compliant with OBDII requirements. The light-duty NGVs that Baytech was able to certify with CARB, based on the results of this project, provides fleet operators NGVs that can be purchased to comply with SCAQMD fleet rules.

### **MATES III Organic Compound Analyses of PM Samples**

Fine particulate matter (PM<sub>2.5</sub>) has been shown to cause adverse health effects and regularly exceeds federal and state standards within the South Coast Air Basin. Sources contributing to fine particulate matter are usually identified and quantified from emission inventories rather than direct measurements. Analyzing specific organic compounds upon collected particulate filters is useful in identifying contributing particulate sources. For example, the cooking contribution to fine particulate matter, specifically cholesterol and palmitoleic acid (animal and vegetable oil), was identified from the analyses conducted under this project.

A goal of the MATES III study was to identify and quantify health risks associated with major known toxic air contaminants within the Basin over a two-year period. An important aspect of the MATES III study was to identify and quantify diesel exhaust which is listed as a toxic air contaminant in the State of California. To identify and quantify the diesel contribution within fine particulate matter, mobile source organic compounds along with other measurements conducted within the SCAQMD laboratory were used.

The Desert Research Institute identified 75 specific organic compounds in PM<sub>2.5</sub> filter samples collected during the MATES III project. The organic compound measurements collected under this contract were used with other SCAQMD laboratory data and source profiles within a mass balance model to identify major primary fine particulate sources. These sources included diesel exhaust, gasoline exhaust, residual oil burning (fuel oil), biomass burning, cooking, sea salt, and geological dust. Using these data, the health risks associated with these different sources were calculated. The following figure shows the resulting air toxics cancer risk per millions for several key pollutants at 11 monitoring sites across the South Coast Air Basin. The source apportionment resulting from this study indicates the dominant risk is due to diesel particulates.



**Figure 14: Air Toxics Cancer Risk by Site**

**Table 5: Projects Completed Between January 1 and December 31, 2007**

<b>Contract</b>	<b>Contractor</b>	<b>Project Title</b>	<b>Date</b>
<b>Incentive Programs-Alternative Fuels</b>			
01151†	Virco Manufacturing	Purchase 30 Electric Forklifts with Two Battery Packs	Dec-07
<b>Infrastructure and Deployment</b>			
01154	R.F. Dickson Company, Inc.	Install CNG Refueling Facility in Downey	Dec-07
04123	Gladstein, Neandross & Associates LLC (GNA)	Demonstrate Low-Emission, Alternative Fuel Heavy-Duty Vehicles within SCAB & Conduct Public Awareness Program	Dec-07
06109	Burnett & Burnette	Update & Expand School Bus Inventory in the Basin	Apr-07
07003	Fontana Unified School District	Install a CNG Refueling Facility for School District	Dec-07
<b>Emission Control Technologies</b>			
04155	Engine Control Systems	Optimize & Demonstrate Oxidation Catalysts to Reduce Emissions from CNG Heavy-Duty Vehicles	Jul-07
<b>Electric/Hybrid Technologies</b>			
05259	AC Propulsion Inc.	Upgrade & Evaluate a Plug-in Hybrid Electric Sedan with Lithium Polymer Batteries	Jul-07
<b>Engine Technologies</b>			
06068	Baytech Corporation	Develop & Demonstrate On-Board Diagnostic Systems for Natural Gas Vehicles	Apr-07
<b>Health Impacts Studies</b>			
05172	Desert Research Institute	Conduct Organic Compound Analyses of Particulate Matter Samples Collected Under MATES III	Jan-07
<b>Outreach and Technology Transfer</b>			
05120†	Clean Fuel Connection, Inc.	Technical Assistance for Technology Incentive Programs to Evaluate Proposals for Compliance	Mar-07
05123†	TIAX LLC	Technical Assistance for Development, Outreach & Commercialization of Low-Emission and Alternative Fuels	Mar-07
05125†	Breakthrough Technologies Institute	Technical Assistance for Development, Outreach & Commercialization of Fuel Cells & Coordination with Federal Agencies	Mar-07
06211†	Gladstein, Neandross & Associates LLC	Co-Host the 3rd Faster Freight, Cleaner Air 2007 Conference	Sep-07
06217†	Electric Power Research Institute	Technical Assistance for AQMD Plug-in Hybrid Electric Vehicle Forum & Roundtable	Mar-07

**Table 5: Projects Completed Between January 1 and December 31, 2007 (Cont'd)**

<b>Contract</b>	<b>Contractor</b>	<b>Project Title</b>	<b>Date</b>
<b>Outreach and Technology Transfer (cont'd)</b>			
07061†	Westart-Calstart	Cosponsor 7 <sup>th</sup> Annual Clean Heavy-Duty Vehicle Conference & 2 <sup>nd</sup> Annual Hydrogen ICE Symposium	Aug-07
07175†	Network Public Affairs, LLC	Technical Assistance for Container Movement Forum & Roundtable	Ju-07
07182†	Alternative Fuel Vehicle Institute	Cosponsor the 13 <sup>th</sup> Alternative Fuels & Vehicles National Conference & Expo	Aug-07
07218†	National Hydrogen Association	Cosponsor the 18 <sup>th</sup> Annual U.S. Hydrogen Conference	Oct-07
07229†	Western Riverside Council of Governments	Cosponsor the 8 <sup>th</sup> Annual WRCCC's Advancing the Choice Event	May-07
07230†	Pacific Merchant Shipping Association	Cosponsor The Clean Ships: Advanced Technology for Clean Air Conference	Oct-07
07240†	Coordinating Research Council Inc.	Cosponsor the 17 <sup>th</sup> Annual CRC On-Road Vehicle Emissions Workshop	Sep-07
07241†	Charles Whyman, Ph.D.	Technical Assistance for Cellulosic Ethanol Forum & Roundtable	Jul-07
07248†	California Climate Action Registry	Cosponsor the California Climate Action Registry's 5 <sup>th</sup> Annual Conference	Oct-07
07257†	Michael Studer, Ph.D.	Technical Assistance for Forum & Roundtable on Cellulosic Ethanol	Jul-07
07262†	Judith Lamare	Technical Assistance for Smog Check Technology Forum & Roundtable	Jul-07
07294†	City of South Pasadena	Cosponsor the First Clean Air Car Show & Film Festival	Aug-07
07302†	Breathe California of Los Angeles County	Cosponsor Environmental & Medical Nanotechnology Innovations Conference	Aug-07
08048†	Westart-Calstart	Cosponsor the Blue Sky Awards 2007	Oct-07

†Two-page summary report (as provided in Appendix C) was not required for level-of-effort contracts or unavailable at time of printing this report.

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## FUTURE TECHNOLOGIES

### Funding Priorities for 2008

The Clean Fuels Program continually seeks to support the deployment of lower emitting technologies. Planning has been and remains an ongoing activity for the program, which must remain flexible to address evolving technologies and the latest progress in the state-of-the-technology. Although the SCAQMD program is significant, especially at a time when both public and private funding available for technology research and development is limited, national and international activities affect the direction of technology trends. The real challenge for the SCAQMD is to identify project or technology opportunities in which its available funding can make a difference in making progressively cleaner technologies a reality in the Basin.

The overall strategy is based in large part on technology needs identified in the AQMP for the Basin and the Governing Board's directives to protect the health of residents of Southern California. The AQMP is the long-term "blueprint" that defines the basin-wide emission reductions needed to achieve ambient air quality standards by 2015, the regulatory measures to achieve those reductions, the timeframes to implement these proposed measures, and the technologies or types of technologies required to meet these future proposed regulations. As previously identified in Figure 1, the NO<sub>x</sub> and VOC emission sources of greatest concern are heavy-duty on-road, off-road, and light-duty on-road vehicles.

In addition to providing for specific control measures based on known technologies and control methods, the Clean Air Act 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. This 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 AQMP.

Within each technical area, 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.

- Technology *development* projects are expected to begin during 2008 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 are expected to result in technologies ready for commercial introduction as soon as 2010. Projects are also proposed that may involve developing 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 2011 or later.
- More mature technologies, those ready to begin field *demonstration* in 2008, are expected to result in a commercial product in the 2009-10 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, it is government's role to support and offset any incremental cost to ensure the transition and use of the cleaner technology. The sustained use and proliferation of these cleaner technologies often depends on this initial support and funding.

## Summary of Technical Priorities

The SCAQMD program maintains flexibility to address dynamically evolving technologies and incorporating the latest progress. The major technical program areas are identified below with specific project categories discussed in more detail in the following section.

Not all project areas will be funded, due to cost-share constraints and the 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.

It should be noted, however, that 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. As such, these technical areas are not listed by priority but rather based on proximity to commercialization and large-scale deployment.

### ***Infrastructure and Deployment***

The importance of refueling infrastructure cannot be overemphasized for the realization of large deployment of alternative fuel technologies. Significant demonstration and commercialization efforts are underway to support the deployment of natural gas vehicles. CNG and LNG refueling stations are being positioned to support public and private fleet applications as incentives for natural gas vehicles are made available to fleet operators.

Besides these technologies, some key issues that must be overcome for public acceptance involve the development of fire and safety codes and standards, cost and economics of the new fuels, public education and training, and emergency response capability. Some of the projects expected to be developed and co-funded for infrastructure development include:

- Development and demonstration of CNG as a vehicle fuel from renewable feedstocks;
- Development and demonstration of advanced, cost effective CNG and LNG stations;
- Deployment of natural gas home refueling appliance for light-duty vehicles;
- Investigation of LNG manufacturing and distribution technologies; and
- Early commercial deployment of alternative fuel light-duty vehicles.



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

The monitoring of pollutants in the Basin is extremely important, especially when focused on a particular sector of the emissions inventory (to identify the technology responsibility) or receptor in the pollution (to assess the potential health risks). Recent 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 from these technologies:

- emissions studies for locomotives, port, and marine vessels;
- demonstrate remote sensing to target different high emission applications;
- conduct studies to identify the health risks associated with ultrafines and ambient particulate matter; and
- emissions studies for low blends of ethanol (E10) and blends of biodiesel (>B20).

### ***Emission Control Technologies***

Although engine technology research is required to reduce the emissions at the combustion source, 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 aftertreatment controls such as particulate matter traps (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 gas 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 ultra-low sulfur diesel and GTL fuels;
- development and demonstration of advanced aftertreatment technologies for mobile applications (including particulate traps and selective catalytic reduction catalysts);
- development and demonstration of low VOC and PM lubricants for diesel and natural gas engines; and
- development and demonstration of advanced air pollution control equipment.

### ***Electric and Hybrid Technologies***

Despite the greater near-term environmental benefits of battery EVs, no major automobile manufacturer is currently producing light-duty passenger EVs. Widespread demand and deployment have also been hampered by public concerns over cost, battery lifetime, travel range, charging station infrastructure and manufacturer commitment. The SCAQMD continues to consider projects addressing these concerns as well as the use of battery EVs in fleet or niche applications.

Most of the major automobile manufacturers are now directing their efforts toward hybrid electric technologies in both light-duty and heavy-duty applications as well as off-road equipment. In particular, diesel and gasoline fueled hybrid electric vehicles and specialty light-duty pure electric vehicles have entered the commercial market. 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, microturbines, and fuel cells for further emission benefits. Opportunities to develop and demonstrate technologies that could enable expedited widespread use of electric and hybrid electric vehicles in the Basin include the following:

- upgrade and demonstration of hybrid electric buses;
- demonstration of advanced commercial utility equipment;
- demonstration of advanced energy storage technologies;
- evaluation and demonstration of light and medium-duty, grid-rechargeable, hybrid electric vehicles (e.g., PHEVs);
- demonstration of heavy-duty hybrid vehicles including hydraulic and series hybrid concepts; and
- development and demonstration of hybrid and electric cargo handling equipment, e.g., linear inductive motors, magnetic levitation, and battery-powered container tugs.

### ***Engine Technologies***

The use of alternative fuels can provide significant reductions in NO<sub>x</sub> and PM emissions, especially in heavy-duty diesel engines for on-road, off-road, and marine applications. Natural gas engines have shown significant promise, with the greatest benefit coming from heavy-duty diesel truck and bus replacement with new natural gas vehicles in urban areas.

In order for alternative fuel heavy-duty engines to achieve commercial acceptance and market penetration, their performance, durability, and cost-effectiveness, in addition to emissions reduction, must be demonstrated to the end user. Future projects will support the development, demonstration, and certification of alternative fuel engines to broaden their application and availability. Specifically, these projects are expected to target the following:

- continued development and demonstration of alternative fuel medium-duty and heavy-duty engines and vehicles;
- demonstration of low- and zero-emission engines for cargo handling activities; and
- development and demonstration of clean alternative fuel engines for non-road applications.

### ***Hydrogen Technologies and Infrastructure***

Although hydrogen as a vehicle fuel remains the ultimate zero-tailpipe emissions, petroleum displacement, and greenhouse gas reduction strategy, technical hurdles have kept fuel cell vehicles from quickly advancing to commercial deployment. The SCAQMD is dedicated to assisting the federal and state governments in commercializing fuel cell vehicles by supporting the required refueling infrastructure. In particular, the production of hydrogen from renewable sources is of interest, either using photovoltaics and electrolyzer technologies or biomass feedstocks and reformation technologies, due to the potential for higher lifecycle efficiencies and lower greenhouse gas emissions compared to conventional fuels. Such renewable energy projects would provide data to help understand and benchmark critical parameters for enabling these technologies.

Furthermore, in order to realize nearer-term air quality benefits, the SCAQMD is actively investigating “bridging” technologies which can fill the gap until fuel cell vehicles become commercially viable. Future projects are expected to include the following:

- development and demonstration of hydrogen-CNG vehicles for medium- and heavy-duty vehicle applications as well as stationary power applications; and
- continued development and demonstration of distributed hydrogen production and refueling stations, including energy stations with electricity and hydrogen co-production and higher pressure (10,000 psi) hydrogen dispensing.

### ***Mobile Fuel Cell Technologies***

As mentioned in the previous section, fuel cell vehicles are of high interest due to their zero-tailpipe emissions, petroleum independence, and reduced greenhouse gas emissions. Considerable research, development, and demonstration efforts are already underway to address these issues by some of the largest automobile manufacturers and fuel suppliers. Yet more work is needed to improve the performance and range of these vehicles, reduce costs, develop a viable fueling infrastructure, and obtain public acceptance for a new technology in everyday applications.

The SCAQMD is actively working with the California Fuel Cell Partnership and the California Hydrogen Highway Network to further the commercialization of mobile fuel cells. The 2008 Plan Update identifies key opportunities consistent with both organizations while clearly leading the way for the development and demonstration of mobile applications. Future projects may include the following:

- 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 and marine applications; and
- demonstration of fuel cell vehicles in controlled fleet applications in the Basin.

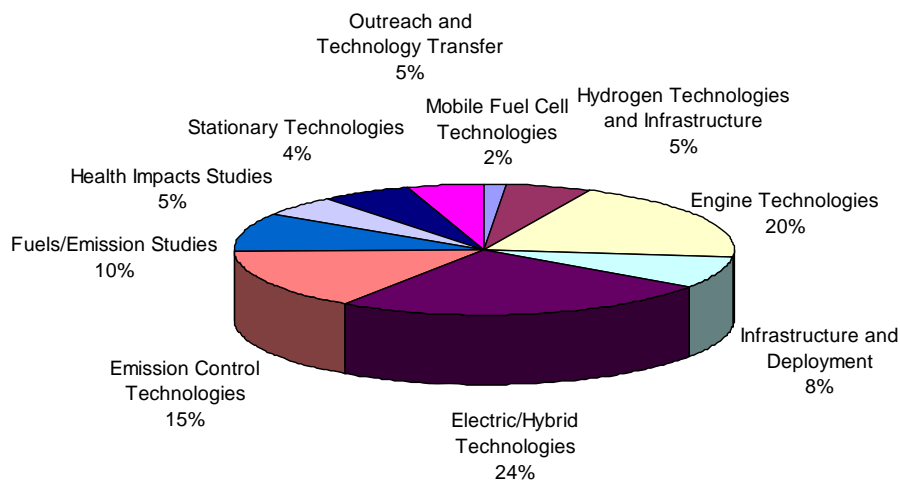
### ***Stationary Clean Fuel Technologies***

Although stationary source emissions are small compared to mobile sources, there are areas where cleaner technology can be applied to reduce NO<sub>x</sub>, VOC, and PM emissions. For example, inspections suggest there is a large population of small combustion generators within the Basin that are operating outside their permit limits due to poor maintenance, deliberate tuning for different performance, operation outside equipment design, or changes in fuel quality. Cleaner, more robust distributed generation technologies exist that could be applied to not only improve air quality, but enhance power quality and reduce electricity distribution congestion. Projects conducted under this category may include:

- development and demonstration of low-emission stationary technologies (e.g., low NO<sub>x</sub> burners, fuel cells, or microturbines), and
- evaluation, development, and demonstration of advanced control technologies for miscellaneous stationary sources.

## Target Project Allocations

Figure 15 below presents the potential allocation of available funding, based on SCAQMD projected program costs of more than \$16.4 million for all potential projects. The expected actual project expenditures for 2008 will be much 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 2008 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 15: Projected Cost Distribution for Potential SCAQMD Projects 2008 & Beyond (\$16.4M)**

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## PROGRAM PLAN UPDATE

This section presents the Clean Fuels Program Plan Update for 2008. The proposed projects are organized by program areas and described in further detail, consistent with the SCAQMD budget, priorities, and the best available information. 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.

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, identification of contractors to perform the projects, host site participation, securing sufficient cost-sharing to complete the project, and other necessary factors. Recommendations to the 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.

The remainder of this section contains the following information for each of the potential projects summarized in Table 6.

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

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

**Expected Total Cost:** The estimated total project cost including the SCAQMD cost share and the cost share of outside organizations expected to be required to complete the proposed project. This is an indication of how much SCAQMD public funds are leveraged through its cooperative efforts.

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

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

**Table 6: Summary of Potential Projects**

<b>Proposed Project</b>	<b>Expected SCAQMD Cost \$</b>	<b>Expected Total Cost \$</b>
<b>Infrastructure and Deployment</b>		
Deploy Natural Gas Vehicles in Various Applications	125,000	5,000,000
Upgrade of Existing Natural Gas Infrastructure	500,000	1,000,000
Develop and Demonstrate Advanced Natural Gas Systems for Refueling Stations	175,000	4,000,000
Demonstrate Manufacturing and Distribution Technologies including Renewables	500,000	7,000,000
Subtotal	\$1,300,000	\$17,000,000
<b>Fuels/Emission Studies</b>		
Conduct Emissions Studies on Biofuels	875,000	1,300,000
Identify and Demonstrate In-Use Fleet Emissions Reductions	500,000	2,000,000
Perform Study of Comparative Emissions of Alternative Fuel and Conventional Fuel Engines	250,000	1,000,000
Subtotal	\$1,625,000	\$4,300,000
<b>Emission Control Technologies</b>		
Develop and Demonstrate Advanced Aftertreatment Technologies	2,000,000	5,200,000
Demonstrate On-Road Technologies in Off-Road and Retrofit Applications	437,500	1,000,000
Subtotal	\$2,437,500	\$6,200,000
<b>Electric/Hybrid Technologies</b>		
Demonstrate Light-Duty Plug-In Hybrid Electric Vehicles	2,000,000	5,000,000
Develop and Demonstrate Medium- and Heavy-Duty Hybrid Vehicles and Systems	912,500	5,000,000
Demonstrate Alternative Energy Storage	500,000	2,600,000
Transfer and Demonstrate Hybrid and Electric Technologies to Conventional Applications	150,000	500,000
Develop and Demonstrate Electric Container Transport Technologies	500,000	5,000,000
Subtotal	\$4,062,500	\$18,100,000
<b>Engine Technologies</b>		
Develop and Demonstrate Advanced Alternative Fuel Medium- and Heavy-Duty Engines and Vehicles	1,000,000	4,000,000
Develop and Demonstrate Alternative Fuel and Clean Conventional Fueled Light-Duty Vehicles	750,000	5,000,000
Develop and Demonstrate Clean Container Transport Technologies	1,500,000	5,000,000
Subtotal	\$3,250,000	\$14,000,000

Table 6: Summary of Potential Projects (Cont'd)

Proposed Project	Expected SCAQMD Cost \$	Expected Total Cost \$
<b>Hydrogen Technologies and Infrastructure</b>		
Develop and Demonstrate Hydrogen Storage Technologies	50,000	1,000,000
Develop and Demonstrate Hydrogen Vehicles	75,000	2,000,000
Develop and Demonstrate Distributed Hydrogen Production and Fueling Stations	762,500	9,000,000
Subtotal	\$887,500	\$12,000,000
<b>Mobile Fuel Cell Technologies</b>		
Develop and Demonstrate Fuel Cells in Vehicle Applications	250,000	3,500,000
Subtotal	\$250,000	\$3,500,000
<b>Health Impacts Studies</b>		
Evaluate Ultrafine Particle Health Effects	312,500	3,000,000
Conduct Monitoring to Assess Environmental Impacts	250,000	1,000,000
Assess Sources and Health Impact of Particulate Matter	250,000	300,000
Subtotal	\$812,500	\$4,300,000
<b>Stationary Clean Fuel Technologies</b>		
Develop and Demonstrate Low-Cost Emission Monitoring Systems	250,000	500,000
Develop and Demonstrate Clean Stationary Technologies	250,000	750,000
Develop and Demonstrate Renewable-Based Energy Generation Alternatives	475,000	1,000,000
Subtotal	\$975,000	\$2,250,000
<b>Outreach and Technology Transfer</b>		
Assessment and Technical Support of Advanced Technologies and Information Dissemination	400,000	800,000
Support for Implementation of Various Clean Fuels Vehicle Incentive Programs	400,000	400,000
Subtotal	\$650,000	\$900,000
<b>TOTALS FOR POTENTIAL PROJECTS</b>	<b>\$16,400,000</b>	<b>\$82,850,000</b>

## ***Infrastructure and Deployment***

**Proposed Project:**     Deploy Natural Gas Vehicles in Various Applications

**Expected SCAQMD Cost:**     \$125,000

**Expected Total Cost:**     \$5,000,000

### **Description of Technology and Application:**

Natural gas vehicles 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.

### **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 the SCAQMD AQMP as well as the state's Alternative Fuels Plan as part of AB1007 (Pavley).



**Proposed Project:** Upgrade of Existing Natural Gas Infrastructure

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

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

**Description of Technology and Application:**

As natural gas fueling equipment begins to age or has been placed in demanding usage, components begin to age and deteriorate. This program 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 the public and school districts.

**Potential Air Quality Benefits:**

While having no direct impact on air emission reductions, new CNG stations will help facilitate the introduction of low-emission, NGVs initially in private and public fleets in the area. Such increased penetration of NGVs will provide direct emissions reductions of NO<sub>x</sub>, VOC, CO, PM, and air toxic compounds throughout the Basin.

**Proposed Project:** Develop and Demonstrate Advanced Natural Gas Systems for Refueling Stations

**Expected SCAQMD Cost:** \$175,000

**Expected Total Cost:** \$4,000,000

**Description of Technology and Application:**

This program would support the development, demonstration and implementation of natural gas fueling station technologies to reduce private investment costs, increase the overall number of such fueling stations in strategic locations throughout the Basin, reduce the cost of natural gas equipment, standardize fueling station design and construction, and provide outreach in two key market segments.

*Small Refueling Stations.* Small private and public fleets are currently constrained in their NGV refueling choices, and do not possess in-house expertise or financial resources to design or install a fueling station. They are also unaware of governing codes or standards affecting such an installation. Providing outreach and financial incentives and reducing the cost and improving the safety, reliability and performance life of fueling station equipment could significantly increase the penetration of natural gas fueling stations.

*Large Fast-Fill NGV Refueling Stations.* Conventional gasoline refueling stations typically refuel between 100 to 300 vehicles per day. The perceived high costs of a fast-fill NGV refueling station that could refuel a similar number of vehicles has significantly curtailed the growth of a NGV refueling infrastructure. The project is intended to provide outreach and financial incentives, advance the technology of compressors, gas-dryers, dispensers, fuel meters, and other major subsystems of a NGV fueling station system. The proposed improvements are expected to improve the performance and lower the capital cost and operating costs of fast-fill NGV refueling stations.

**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 would significantly reduce the installation and operating costs of NGV refueling stations, besides improving the refueling time. This would lead to the expansion of the NGV fueling infrastructure and greater consumer acceptance, which in turn should support expedited commercial implementation of NGVs. The increased exposure and fleet and consumer acceptance of NGVs would lead to significant and direct reductions in NO<sub>x</sub>, VOC, CO, PM, and toxic compound emissions from mobile sources.

**Proposed Project:** Demonstrate Manufacturing and Distribution Technologies including Renewables

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

**Expected Total Cost:** \$7,000,000

**Description of Technology and Application:**

Lack of 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 the 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;
- 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 the significant penetration of zero- and low-emission vehicles in the South Coast Basin to attain federal clean air standards by 2015. 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 NO<sub>x</sub>, PM, and toxic compound emissions.

## ***Fuels/Emission Studies***

**Proposed Project:** Conduct Emissions Studies on Biofuels

**Expected SCAQMD Cost:** \$875,000

**Expected Total Cost:** \$1,300,000

### **Description of Technology and Application:**

Biofuels are one potentially important strategy to reduce petroleum dependence, air pollution and greenhouse gases. Biofuels are in fact receiving increased attention due to national support of and state activities resulting from AB 32, AB 1007, and the Low-Carbon Fuel Standard. These efforts are necessary to address the promulgation and deployment of low greenhouse gas emitting fuels and technologies if the state hopes to meet the 2020 target to reduce GHG emissions to 1990 levels as required by AB 32. However, to ensure that such fuels and technologies have low criteria pollutant emissions, specifically NO<sub>x</sub> and PM, the emissions from lower carbon fuels, such as blends of biodiesel and ethanol, must be further analyzed.

In various diesel engine studies, replacement of petroleum diesel fuel with biodiesel fuel has demonstrated reduced PM, CO, and air toxics emissions. Biodiesel is also promoted to reduce greenhouse gas emissions because it can be made from renewable feedstocks, such as soy and canola. Biodiesel can be formulated at varying percentages by blending with petroleum diesel fuel and is commonly used at 20 percent or B20 to avoid congealing at cold temperatures and possible engine seal and gasket damage which can occur with 100% biodiesel (B100). Biodiesel and biodiesel blends, however, have demonstrated a tendency to increase NO<sub>x</sub> emissions, which exacerbates the ozone and PM<sub>2.5</sub> challenges faced in the Basin.

Ethanol is another biofuel that is gaining increased national media and state regulatory attention. The amount of ethanol in gasoline is currently 5.7% or E6 to replace the banned MTBE as an oxygenate to reduce CO emissions. There are efforts to further increase the ethanol content to 10% or E10 and higher as a means to increase the amount of renewable fuels in the state. Contemporary light-duty vehicles, however, are not equipped to manage increased levels of ethanol and could result in higher criteria pollutant emissions. As such, an investigation into the tailpipe emissions for commercial gasoline (E6), the certification fuel which is still based on MTBE gasoline, and higher ethanol blends (e.g., E10) is warranted.

In December 2007, the Governing Board approved two projects involving emission studies on biofuels. The first project will evaluate the emissions from using biodiesel derived from current and future feedstocks common to California at different blend levels (B5, B20, B50, and B100). This study will include a wide range of pollutants including criteria, toxics, greenhouse gases, and non-regulated pollutants. The study will evaluate test engines and vehicles that are common to California and test cycles that represent a range of driving conditions. The study will also evaluate the NO<sub>x</sub> impact and investigate possible NO<sub>x</sub> mitigation strategies, which may include fuel reformulation, additives and/or minor injection timing changes. The second project will evaluate the emissions from using five different ethanol-gasoline blends in light-duty vehicles. The results of these two projects may provide direction for the next step as well as identify areas that may need to be addressed in future projects.

**Potential Air Quality Benefits:**

If biodiesel and biodiesel blends can be demonstrated to reduce air pollutant emissions with the ability to mitigate any NO<sub>x</sub> impact, this technology will become a viable strategy to assist in meeting air pollutant standards as well as the goals of AB32 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 (NO<sub>x</sub> impact) that may result from using this alternative fuel. With reliable information on the emissions from using biodiesel and biodiesel blends, the AQMD can take actions to ensure the use of biodiesel will obtain air pollutant reductions without creating additional NO<sub>x</sub> emissions that may exacerbate the basin's ozone problem.

**Proposed Project:** Identify and Demonstrate In-Use Fleet Emissions Reductions

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

**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. Unfortunately, the in-use fleet--particularly heavy-duty engines in trucks, buses, construction equipment, locomotives, marine vessels, and cargo handling equipment--has 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 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); and
- electrical auxiliary power unit replacements.

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

**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, which is included in Chapter 4 of the 2007 AQMP as a potential control strategy.

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**Proposed Project:** Perform Study of Comparative Emissions of Alternative Fuel and Conventional Fuel Engines

**Expected SCAQMD Cost:** \$250,000

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

**Description of Technology and Application:**

Various makes and models of heavy-duty engines using alternative fuels have been developed and deployed in the Basin. The certification procedure requires laboratory tests on the engine emissions performance as well as those of conventional heavy-duty diesel engines. It is important to assess the emissions performance of these engines in actual operation to determine if the engines are operating properly and the expected benefits of alternative fuels are being realized, including potential toxic emissions.

The objective of this project is to assess the on-road emission performance of heavy-duty engines using alternative fuels, including natural gas, dual fuel, and emerging liquid fuels such as Fischer-Tropsch liquids. The testing of equivalent heavy-duty engines using baseline fuels is needed to assess the relative emission performance. Diagnostic procedures will also be performed to help identify any mal-performing system.

Another emerging area of interest is the emissions from biofuels, especially low level blends of ethanol and high level blends of biodiesel. Low level blends of ethanol (E10) may have increased permeation and evaporative emissions from light duty vehicles. Also, a mixture of ethanol concentrations, e.g., between E10 and E85, has unknown tailpipe emissions, so a study to understand these effects is desired. Although there have been extensive studies conducted to quantify tailpipe emissions from biodiesel blends, an in-use emissions study would be useful to quantify the actual performance on a case-by-case basis.

**Potential Air Quality Benefits:**

This proposed program supports several 2003 AQMP On-Road Mobile Sources Control Measures, including M4, "Heavy-Duty Diesel Vehicles; Early Introduction of Low-NO<sub>x</sub> Engines" and M5, "Heavy-Duty Diesel Vehicles; Additional NO<sub>x</sub> Reductions in California." Certification of low-emission vehicles and engines, and their integration into the Basin's transportation sector, is a high priority under the AQMP and the SIP. In addition, the identification of diesel exhaust particulate as a toxic air contaminant by CARB and the determination that diesel exhaust contributes over 70 percent of the increased cancer risk due to air pollution in the Basin suggest an urgency to expedite the implementation of clean alternatives to diesel engines to protect public health.

This program is intended to evaluate low-emission alternative fuel heavy-duty engine technology and compare such emissions to heavy-duty diesel emissions. For example, the expected benefit of replacing one 4.0 g/bhp-hr heavy-duty diesel engine with a 2.0 g/bhp-hr natural gas engine in a vehicle that consumes 10,000 gallons of fuel per year is about 800 lb/yr. This proposed project will also determine in-use emission performance and provide an indication of actual vs. certified performance.

## **Emission Control Technologies**

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

**Expected SCAQMD Cost:** \$2,000,000

**Expected Total Cost:** \$5,200,000

### **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 NO<sub>x</sub> 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, NO<sub>x</sub>, CO, carbonyl, and hydrocarbon emissions in retrofit and new applications.

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 emissions control technologies, such as DPFs and oxidation catalysts, to the non-road sector is a potentially low-risk endeavor that can have immediate emissions reductions. Further development and demonstration of other technologies, such as SCR and NO<sub>x</sub> adsorbers, could also have NO<sub>x</sub> reductions of up to 90%.



**Proposed Project:** Demonstrate On-Road Technologies in Off-Road and Retrofit Applications**Expected SCAQMD Cost:** \$437,500**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 NO<sub>x</sub> in 2004 to 0.2 g/bhp-hr NO<sub>x</sub> in 2007, which is an order of magnitude decrease in just three years. Off-road engines, however, have considerably higher emissions limits depending on the engine size. For example, Tier-3 standards, which took effect in 2006, require only 3 g/bhp-hr NO<sub>x</sub>. 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
- application of 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.

## ***Electric/Hybrid Technologies***

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

**Expected SCAQMD Cost:** \$2,000,000

**Expected Total Cost:** \$5,000,000

### **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 electric vehicles integrate a small internal combustion engine, battery pack, and electric drive motors to improve fuel economy (e.g., Honda Insight) or performance (e.g., Lexus RX400h).

The SCAQMD has long supported the concept of using increased batteries 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 electric vehicle strategy allows reduced emissions and improved fuel economy. Unfortunately, no automobile manufacturer is openly pursuing this strategy.

This project category is to develop and demonstrate: (1) various HEV architectures; (2) anticipated costs for such architectures; (3) customer interest and preferences for each alternative; (4) prospective commercialization issues and strategies for various alternatives; and (5) integration of the technologies into prototype vehicles and fleets to demonstrate the viability and clean air benefits of these types of vehicles.

Innovative approaches to HEV systems are also under development that could improve performance, fuel efficiency, and reduce emissions relative to the first HEVs commercially introduced. Innovations that may be considered for demonstration include: advancements in the auxiliary power unit, either ICE or other heat engine, especially using alternative fuels including natural gas and hydrogen; battery-dominant hybrid systems utilizing off-peak re-charging; and advanced battery technologies such as lithium-ion. Both new designs and retrofittable technologies will be considered.

### **Potential Air Quality Benefits:**

The 2007 AQMP identifies zero- or near zero-emitting vehicles as a key attainment strategy. HEV technologies have the potential to achieve near-zero emissions but with the range of a conventional gasoline-fueled vehicle, a factor expected to enhance consumer acceptance. This proposed project will evaluate various HEV systems and their performance and identify the most appropriate protocols with which to test real-world HEVs. Given the variety of HEV systems under development, it is critical to determine the true emissions and performance of HEVs. Demonstration of optimized prototypes would improve the viability of near-ZEV HEV technologies and enhance the deployment of near-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 original equipment manufacturers to expedite introduction of near-zero emitting vehicles in the South Coast Basin, which is a high priority of the AQMP.

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**Proposed Project:** Develop and Demonstrate Medium- and Heavy-Duty Hybrid Vehicles and Systems

**Expected SCAQMD Cost:** \$912,500

**Expected Total Cost:** \$5,000,000

**Description of Technology and Application:**

Hybrid technologies have gained momentum in the light-duty sector with commercial offerings by most all 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.

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 (PHEV) utilizing off-peak re-charging; and hydraulic energy storage technologies where applicable. Alternative fuels are preferred in these projects, e.g., natural gas, 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 retrofittable technologies will be considered.

**Potential Air Quality Benefits:**

The 2007 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 original equipment manufacturers 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:** \$500,000

**Expected Total Cost:** \$2,600,000

**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 lead acid and nickel-cadmium battery packs. Over the past few years, additional technology consisting of nickel sodium chloride and lithium-ion batteries has shown robust performance. Other technology manufacturers have also developed energy storage devices including flywheels, hydraulic systems, and ultracapacitors. 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 program is to decrease the fuel consumption without any changes in performance compared to conventional vehicles. This program 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 2007 AQMP. This program is expected to develop hybrid 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 and toxic pollutants.

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**Proposed Project:**     Transfer and Demonstrate Hybrid and Electric Technologies to Conventional Applications

**Expected SCAQMD Cost:**     \$150,000

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

**Description of Technology and Application:**

Current battery electric technology may be applicable to a number of applications beyond conventional passenger cars. For example, studies conducted by a number of different parties suggest that a high percentage of consumer/commuter driving patterns total no more than 25 miles a day. From an air quality perspective, it may be particularly advantageous to identify and implement zero-emission vehicles in conditions where low mileage and heavy stop-and-go duty cycles are prevalent.

The objective of this program area is to identify and demonstrate applications that can best utilize zero- and near zero-emission technologies, such as neighborhood electric vehicles, electric scooters, passenger trams, and low-speed cargo tugs. Applications to be included in this program include, but are not limited to, station cars, shared cars, fixed route fleets, and other innovative applications, with potential linkages to transit through intelligent transportation systems.

The development of energy efficient systems reduces emissions associated with energy generation and is a criterion for projects funded under this category.

**Potential Air Quality Benefits:**

The 2007 AQMP identifies zero- and nearly zero-emitting ventures as a key attainment strategy. This project would demonstrate the viability of zero-emission technologies in innovative applications. Other benefits would include increased exposure and user acceptance of advanced technologies, direct emission reductions from in-basin demonstrations, and the potential for increased use, and resulting emission reductions of the demonstrated technologies through their expedited commercialization.

**Proposed Project:**     Develop and Demonstrate Electric Container Transport Technologies

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

**Expected Total Cost:**         \$5,000,000

**Description of Technology and Application:**

Advanced transport systems can be used to transfer cargo containers from the ports to both local and “distant” intermodal facilities, thereby significantly reducing emissions from on-road trucks and locomotives. Such systems use magnetic levitation (maglev), linear synchronous motors or linear induction motors on dedicated guideways. 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 the berm of or elevated above existing river flood control channels. Container freight systems are not designed to carry any operators or passengers on the guideways. Current container transport concepts have been developed by General Atomics with California State University, Long Beach (GA-CSULB) and the Texas Transportation Institute (TTI). GA-CSULB has built a prototype system at GA’s San Diego facility using maglev. This Electric Cargo Conveyor (ECCO) demonstration moves 20-foot containers. The elevated ECCO system costs about \$100M per mile and \$1.50 per container-mile for operation. TTI’s concept for its “Freight Shuttle System” (FSS) uses linear induction propulsion in combination with steel wheels on a flat steel running surface, similar to conventional rail. The elevated FSS system costs about \$20M per mile and \$0.10 per mile in operating costs. Both systems utilize a lightweight carriage in which the containers are carried. Automatic cranes can be used to load and unload the containers.

**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 2007 AQMP proposes to reduce emissions from this activity by modernizing the fleet and retrofitting NO<sub>x</sub> 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. These use electric propulsion for the containers on fixed guideways and eliminate local diesel truck emissions. The emission benefits have not yet been estimated because the fate of the displaced trucks has not been determined.

## **Engine Technologies**

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

**Expected SCAQMD Cost:** \$1,000,000

**Expected Total Cost:** \$4,000,000

### **Description of Technology and Application:**

The objective of this proposed program 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 NO<sub>x</sub> emissions target for this program area is 0.2 g/bhp-hr and PM emissions target is below 0.01 g/bhp-hr. This program is expected to result in several projects, including:

- demonstration of advanced engines in medium-duty and heavy-duty vehicles;
- development of durable and reliable retrofit technologies to 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 program 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 has 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 program 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 1400 lb/yr of NO<sub>x</sub>. 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 program 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 program to comply with SCAQMD fleet regulations.

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

**Expected SCAQMD Cost:** \$750,000

**Expected Total Cost:** \$5,000,000

**Description of Technology and Application:**

Although new conventional 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, gas-to-liquid (GTL), bio-diesel, and ultra low-sulfur diesel. 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; and
- assessment of “clean diesel” vehicles, including hybrids, and their ability to attain SULEV standards.

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

**Potential Air Quality Benefits:**

The 2007 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 program is expected to lead to increased availability of low-emission alternative-and conventional-fueled vehicles for fleets as well as consumer purchase.



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**Proposed Project:** Develop and Demonstrate Clean Container Transport Technologies

**Expected SCAQMD Cost:** \$1,500,000

**Expected Total Cost:** \$5,000,000

**Description of Technology and Application:**

At the ports of San Pedro Bay, cargo containers are moved from the docks either by railroad train or by truck. Generally speaking, railroad trains move containers long distances (greater than 500 miles) while trucks are used for shorter hauls (less than 400 miles). Because of limited rail capacity at the dock, many containers are also moved individually by truck to railroad intermodal yards 4 to 20 miles away (drayage) where the containers are then loaded on to trains for their long-distance trips. In order to reduce truck emissions and roadway congestion, various systems have been proposed to move containers over dedicated guideways using electrical propulsion. However, such systems cost from \$20M to \$100M per mile to construct. Two alternatives have been proposed: 1) short-haul shuttle trains using ultra-low-emission locomotives; 2) and drayage truck trains with multiple container trailers using ultra low-emission truck tractors. Ultra low-emission technologies such as LNG, CNG, SCR, particulate filters including DPFs, diesel oxidation catalysts (DOCs), and hybrid drive trains are available for locomotives and truck tractors.

It is proposed that a short-haul shuttle train with ultra low-emission locomotives be demonstrated in the South Coast Air Basin. This will involve developing and demonstrating the above stated emission technologies on freight locomotives. In addition, a system for building such trains will need to be developed for locally bound containers, likely at the railroad intermodal yards. While the economics of a shuttle train will be less attractive than a long-haul train, the cost effectiveness for emission reductions will be competitive with other emission strategies when considering the reductions from displaced trucks and eliminated traffic congestion.

The second proposal is to develop and demonstrate “truck container trains” to minimize drayage emissions. Such “trains” would use low-emission natural-gas truck tractors and travel at reduced speeds on either dedicated lanes on existing roadways, or on dedicated roadways. In order for such a system to be viable, the natural-gas truck tractors would need to be reconfigured to handle the excessive load of multiple trailers as well as to minimize emissions. Also, existing container trailer chassis would need to be revised in order to handle tandem trailers. (Three-trailer trucks are allowed on highways in certain states, and four-trailer trucks are used in Australia). This project would develop the specifications for the natural-gas truck tractor, determine the optimum number of containers that could be trailored, determine a specification for the revised container trailer chassis and suggest regulatory and legislative changes that would be needed for operating such a system. Following this design effort, a demonstration project would be expected.

**Potential Air Quality Benefits:**

On-road heavy-duty diesel trucks are an integral part of operations at the ports by moving cargo containers into the Basin and beyond. The 2007 AQMP proposes to reduce emissions from this activity by modernizing the fleet and retrofitting NO<sub>x</sub> and PM emission controls on older trucks. An alternative approach is to use “advanced container transport systems” which cost from \$20M to \$100M per mile for about 5 miles. The proposed short-haul shuttle train with ultra-low-emission locomotives will cost much less and eliminate one to two hundred truck trips per train from the ports and the associated traffic congestion. Similarly, the truck container train will cost much less than the container transport system and have emission benefits greater than modernizing or retrofitting the fleet because fewer truck tractors will be needed. Nonetheless, new truck tractors and revised container trailer chassis will need to be developed and purchased with a net cost probably more than

modernizing the fleet. However, the emission benefits will be greater and proportional to the number of containers included in the container train since one truck trip will be eliminated for each extra container.

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## ***Hydrogen Technologies and Infrastructure***

**Proposed Project:** Develop and Demonstrate Hydrogen Storage Technologies

**Expected SCAQMD Cost:** \$50,000

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

### **Description of Technology and Application:**

One of the critical barriers for fuel cell and hydrogen vehicle commercialization is the need for increased on-board hydrogen storage. The complexity and safety issues associated with storing hydrogen in large enough quantities to provide sufficient vehicle range are the subjects of a national effort through the DOE. Projects under this category may include joint efforts with the DOE and other stakeholders to develop and demonstrate hydrogen storage technologies such as metal hydrides, higher pressure tanks, and additional hydrogen storage tank options. Increased hybridization and battery capacity may also be considered.

### **Potential Air Quality Benefits:**

The 2007 AQMP identifies the need to implement zero-emission vehicles. SCAQMD adopted fleet regulations requiring 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 and near-zero emission ICE vehicles operating on hydrogen fuel. The proposed projects have the potential to accelerate the commercial viability of fuel cell and hydrogen 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 widescale 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:** Develop and Demonstrate Hydrogen Vehicles

**Expected SCAQMD Cost:** \$75,000

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

**Description of Technology and Application:**

The SCAQMD has been involved in the development and demonstration of light-duty and heavy-duty vehicles operating on hydrogen as their primary fuel including a full-size transit bus. Hydrogen burning ICE vehicles provide a transition platform to advance hydrogen refueling technologies, gain valuable experience with hydrogen as a vehicle fuel, and promote cleaner fuels to the public. The proposed project category is to continue developing and demonstrating additional platforms, including light-duty vehicles, which can be utilized in city fleets, and medium-duty shuttles, which can be operated in city and airport fleets.

**Potential Air Quality Benefits:**

Certification of low-emission vehicles and engines and their integration into the Basin's transportation sector are a high priority under the 2007 AQMP. This program is expected to develop hybrid 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 and toxic pollutants.

**Proposed Project:** Develop and Demonstrate Distributed Hydrogen Production and Fueling Stations**Expected SCAQMD Cost:** \$762,500**Expected Total Cost:** \$9,000,000**Description of Technology and Application:**

Alternative fuels, such as hydrogen, and the use of advanced technologies, such as fuel cell vehicles, may be 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 an 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 program 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, 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. Similar to the natural gas home refueling appliance currently commercially available, 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.

**Potential Air Quality Benefits:**

The 2007 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 program 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 NO<sub>x</sub>, VOC, CO, PM, and toxic compound emissions from vehicles.

## **Mobile Fuel Cell Technologies**

**Proposed Project:** Develop and Demonstrate Fuel Cells in Vehicle Applications

**Expected SCAQMD Cost:** \$250,000

**Expected Total Cost:** \$3,500,000

### **Description of Technology and Application:**

This proposed project would support the demonstration of promising fuel cell technologies for applications using direct hydrogen in proton exchange membrane (PEM) fuel cell technologies. Battery 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.

With the implementation of the California Hydrogen Highway Network, supplemented by the existing and planned hydrogen refueling stations in the Southern California area, pre-production vehicles are planned for demonstration in controlled fleets, such as local cities, transit authorities, and airports. Some of these pre-production vehicles include light-duty trucks as well as small to full size transit and shuttle buses. 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. 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. This category may include projects in the following applications:

#### **On-Road:**

- Light-Duty Vehicles
- Transit Buses
- Shuttle Buses
- Medium-Duty Trucks (Utility or Other)

#### **Non-Road:**

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

### **Potential Air Quality Benefits:**

The 2007 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 widescale 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.

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## **Health Impacts Studies**

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

**Expected SCAQMD Cost:** \$312,500

**Expected Total Cost:** \$3,000,000

**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, recent health studies indicate that the ultrafine portion of particulate matter may be more toxic than other fractions. Several technologies have been introduced and 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. To have a better understanding of changes in ultrafine particulate emissions from the application of these 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 program, engine or chassis dynamometer testing will 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, etc. These tests may also include comparisons with the application of particulate matter retrofit traps. This program needs to be closely coordinated with the development of new aftertreatment technologies for alternative fuels and new engines. Additionally, epidemiologic and toxicological studies will be conducted as well as measurements of ambient levels to better understand the health effects and potential community exposures from ultrafine particles.

**Potential Air Quality Benefits:**

The 2007 AQMP relies on the significant penetration of low-emission vehicles in the South Coast Basin to attain federal clean air standards by 2010. Reduction of particulate emissions from the use of diesel fuel 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:** \$250,000

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

**Description of Technology and Application:**

Facilities, buildings, structures, or highways which attract mobile sources of pollution are considered “indirect” sources. Ambient 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. The SCAQMD is currently monitoring particulate air quality at several Long Beach sites, Wilmington, and Carson. This project category would identify other areas of interest to conduct ambient air monitoring, conduct the emissions monitoring, analyze the data, and assess the health impacts from the 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 indirect 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:** \$250,000**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.

The measurement of organic compounds as tracers from specific sources is a technique that has been used in numerous source apportionment studies and published within the scientific literature. The resulting data on levels of tracers can be evaluated using Chemical Mass Balance Models and other source apportionment techniques, such as Positive Matrix Factorization, to estimate source contributions to particulate matter. The resulting estimates of ambient diesel particulate matter can then be used to assess potential health risks.

Additionally, other related studies may be conducted, 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.

**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. 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.

## **Stationary Clean Fuel Technologies**

**Proposed Project:** Develop and Demonstrate Low-Cost Emission Monitoring Systems

**Expected SCAQMD Cost:** \$250,000

**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. 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 NO<sub>x</sub> 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 NO<sub>x</sub> 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.

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 O<sub>2</sub> sensor known as a wide-band O<sub>2</sub> sensor, is another alternative that can be analyzed. A more technical approach might to deploy technology utilizing the O<sub>2</sub> signature of a post-catalyst O<sub>2</sub> 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:**

The 2007 AQMP indicates that in 2010 stationary sources, i.e., stationary engines, boilers, heaters, furnaces and ovens, will account for about 11 percent of total NO<sub>x</sub> 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 NO<sub>x</sub> and/or CO emissions above levels required in their permits. Projects could potentially reduce a significant class of NO<sub>x</sub> 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 NO<sub>x</sub> technologies (burners and ICEs);
- low-Btu gas technologies (e.g., digester, landfill, or dairy 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; and
- fumes-to-fuel technology to replace thermal oxidizers and capture VOC emissions for electricity generation.

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 NO<sub>x</sub>, 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 PM<sub>2.5</sub> standards.

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

**Expected SCAQMD Cost:** \$475,000

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

**Description of Technology and Application:**

The objective of this proposed program 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; 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, using 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 program 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, improve reliability and user friendliness, and identify markets that could expedite the implementation of successful technologies.

**Potential Air Quality Benefits:**

The 2007 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 program 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.

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## ***Outreach and Technology Transfer***

**Proposed Project:** Assessment and Technical Support of Advanced Technologies and Information Dissemination

**Expected SCAQMD Cost:** \$400,000

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

### **Description of Project:**

This program 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 program is to expedite the transfer of technology developed as a result of Technology Advancement projects to the public domain, industry, regulatory agencies, and the scientific community. This program 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 program 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 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 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 for Implementation of Various Clean Fuels Vehicle Incentive Programs

**Expected SCAQMD Cost:** \$400,000

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

**Description of Project:**

This program supports the implementation of zero-emission vehicle incentives program, 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 NO<sub>x</sub> and PM emissions in the basin in addition to reducing toxic air contaminants.

**Appendix A**  
**SCAQMD Advisory Groups**





## Technology Advancement Advisory Group

Tom Cackette .....	California Air Resources Board
Tim Carmichael.....	Coalition for Clean Air
Dr. Blair Folsom.....	Independent Consultant in Combustion Technology
James Uihlein .....	Chevron
John D. Harper, Jr.....	Small Business Coalition
Philip J. Hodgetts .....	Clean Air Now
<i>Pending Appointment</i> .....	U.S. Department of Transportation
Dr. Sigmund Gronich.....	U.S. Department of Energy
<i>Pending Appointment</i> .....	Port-Related
Charles Mitzutani .....	California Energy Commission
Dan Moran.....	Quality Body Works
Lee Wallace.....	Sempra Energy
William R. West.....	Southern California Edison

## SB 98 Clean Fuels Advisory Group

Tom Plenys.....	Coalition for Clean Air
Dr. Blair Folsom.....	Independent Consultant in Combustion Technology
Dr. John Froines .....	UCLA Center for Occupational and Environmental Health/UCLA School of Public Health
Dr. Fritz Kalhammer .....	Independent Consultant in Energy and Process Technology
Jason Mark .....	Energy Foundation
Dr. Melanie Marty.....	Office of Environmental Health Hazard Assessment
Dr. Wayne Miller .....	Center for Environmental Research and Technology University of California, Riverside
Dr. Vernon Roan .....	Center for Advanced Studies in Engineering University of Florida
Brian Runkel.....	California Environmental Business Council, Inc.
Dr. Scott Samuelsen .....	Combustion Laboratory/National Fuel Cell Research Center/University of California, Irvine
Dr. George Sverdrup .....	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, 2008**



Contract	Contractor	Project Title	Start Term	End Term	AQMD \$	Project Total \$
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**Incentive Programs-Alternative Fuels**

01157	Waste Management of Los Angeles	Purchase 20 Natural Gas Refuse Trucks	02/27/02	06/30/08	394,278	829,200
01159	Waste Management of San Gabriel	Purchase 20 CNG Refuse Collection Trucks	07/31/02	06/30/08	829,200	829,200
01160	Waste Management of the Desert	Repower Seven Roll-Off Refuse Trucks to LNG	10/03/01	06/30/08	75,221	526,547
04167	Foothill Transit	Purchase 75 CNG Transit Buses under FY 2002-03 Carl Moyer Program	05/25/05	01/31/10	727,500	727,500
04169	City of Santa Monica	Purchase 57 New LNG Transit Buses under FY 2002-03 Carl Moyer Program	08/04/04	09/30/10	407,732	407,732
04170	Mellon Grading, Inc.	Repower One Each of Diesel Water Hauler, Diesel Crawler Tractor, Diesel Crawler Tractor Loader	10/01/04	12/31/10	140,450	140,450
04171	City of Santa Clarita	Purchase 12 New CNG Transit Buses under FY 2002-03 Carl Moyer Program	07/28/04	07/31/10	126,000	4,203,432

**Infrastructure and Deployment**

03098	Taormina Industries	Develop LNG-L/CNG Refueling Station	11/26/02	07/31/09	203,682	1,059,850
03099	Sanitation Districts of Los Angeles County	Purchase & Install LNG-L/CNG Refueling Station at Puente Hills Landfill Facility	02/10/03	07/31/08	560,000	1,120,000
03102	USA Waste of California, Inc.	Purchase & Install LNG-L/CNG Refueling System at La Metro Hauling District	06/26/03	06/30/08	400,000	850,000
03103	Waste Management Recycling and Disposal Services	Develop LNG-L/CNG Refueling Station	10/23/03	12/31/08	400,000	850,000
04015	WM Energy Solutions, Inc.	LNG Production at Bradley Landfill	11/06/03	09/30/09	300,000	5,277,000
04085	City of Banning	Construct Natural Gas Refueling Station	03/26/04	08/31/09	140,000	725,000
05109	Orange County Sanitation Districts	Upgrade CNG Refueling Station in Fountain Valley	02/04/05	02/28/10	24,000	80,000
05135	Sysco Food Services of Los Angeles, Inc.	Purchase & Install New LNG Refueling Station at City of Walnut Food Distribution Center	05/25/05	03/31/10	250,000	1,102,476
05250	Downs Commercial Fueling, Inc.	Purchase & Install New L/CNG Refueling System at Commercial Refueling Station in Temecula	11/04/05	12/31/10	203,137	833,333
06000	Gas Equipment Systems, Inc.	Purchase & Install New CNG Refueling System at County of LA Dept. of Beaches and Harbors' Malibu Facility	09/05/06	12/31/12	150,000	525,000
06017	Fuelmaker Corporation	Incentive Buydown Program for CNG Home Refueling Appliance	09/26/05	03/31/08	350,000	450,000
06018	American Honda Motor Co. Inc.	Incentive Buydown Program for CNG Home Refueling Appliance	11/02/05	03/31/08	50,000	100,000

<b>Contract</b>	<b>Contractor</b>	<b>Project Title</b>	<b>Start Term</b>	<b>End Term</b>	<b>AQMD \$</b>	<b>Project Total \$</b>
<b>Infrastructure and Deployment (cont'd)</b>						
06028	Consolidated Disposal Service, LLC	Purchase & Install CNG Fueling System at Long Beach Waste Transfer Station	11/23/05	12/31/11	222,038	740,127
06029	Clean Energy	Upgrade CNG Refueling Station at SoCalGas Santa Monica Facility	10/26/05	12/31/11	190,000	634,500
06030	Clean Energy	Purchase & Install CNG Refueling Station at Foothill Transit's Pomona Facility	04/13/06	12/31/11	92,506	250,000
06031	R.F. Dickson Company, Inc.	Upgrade CNG Station at Bellflower Facility	04/13/06	12/31/11	211,148	703,828
06042	UCLA Fleet & Transit Services	Upgrade Existing CNG Public Access Station with Dispenser & Card Reader	09/05/06	12/31/11	15,921	31,842
06043	County Sanitation Districts of Los Angeles	Purchase & Install CNG Fueling Station at Joint Water Pollution Control Plant in Carson City	03/10/06	12/31/11	250,000	850,000
06074	City of Sierra Madre	Purchase & Install New Public Access CNG Refueling Station at City Yard	03/16/06	12/31/11	73,776	368,880
06082	Clean Energy	Purchase & Install New 24-Hour Public Access CNG Refueling Station at SoCalGas's Canoga Park Facility	03/13/06	12/31/11	250,000	842,050
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	12/31/11	120,000	400,000
06091	City of Whittier	Purchase & Install New Public Access CNG Refueling Station at City Yard	03/18/06	12/31/11	150,000	450,000
06139	Lake Elsinore Unified School District	Purchase & Install New Public Access CNG Refueling Station at Maintenance Yard	06/29/06	12/31/11	128,000	367,000
06237	Whittier Union High School District	Upgrade Existing Public Access Station with New Dispenser and Card Reader	10/02/06	12/31/12	15,921	31,842
06238	Gas Equipment Systems Inc.	Purchase & Install New CNG Refueling Systems at City of San Fernando Public Works Dept Yard	12/15/06	12/31/12	73,200	405,000
07014	Gas Equipment Systems Inc.	Purchase & Install New CNG Refueling System at County of Los Angeles, Dept. of Beaches & Harbors Facility In Zuma Beach	12/15/06	12/31/12	150,000	525,000
07051	City of Pasadena	Purchase & Install New Public Access CNG Refueling Station	12/28/06	12/31/12	165,000	550,000
07149	City of San Bernardino	Purchase & Install New Public Access LNG-L/CNG Refueling Station at City of San Bernardino Municipal Service Yard	06/25/07	12/31/12	164,861	1,399,110
07151	Menifee Unified School District	Purchase & Install New Public Access CNG Refueling Station	01/25/07	12/31/12	75,000	414,500
07152	Newport-Mesa Unified School District	Purchase & Install New Limited Public Access CNG Refueling Station	05/16/07	12/31/12	150,000	375,000

Contract	Contractor	Project Title	Start Term	End Term	AQMD \$	Project Total \$
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**Infrastructure and Deployment (cont'd)**

07243	City of Commerce	Purchase & Install New Public Access L/CNG Refueling Station	05/16/07	12/31/12	250,000	1,300,000
07244	SunLine Transit Agency	Upgrade Existing Public Access CNG Refueling Stations in Thousand Palms & Indio	04/04/07	12/31/12	90,000	180,000
07253	Colton Joint Unified School District	Local Match to Purchase & Install CNG Refueling Station	03/19/07	05/15/08	170,000	1,348,408
07320	Orange County Transportation Authority	Install New CNG Refueling Station in the City of Santa Ana	12/21/07	12/31/12	350,000	5,841,729
08033-1	California Air Resources Board	Demonstrate LPG Stop-Fill Unit	06/25/07	06/24/10	75,000	498,900
08101	Pupil Transportation Cooperative	Upgrade Existing Public Access CNG Refueling Station	12/31/07	12/31/13	187,154	300,000

**Fuels/Emission Studies**

00188	University of California, Riverside	Testing Support & Emissions Assessment	07/17/00	07/01/08	100,000	100,000
06157	City of Santa Monica	Develop & Demonstrate Biodiesel Fuel with Selective Catalytic Reduction	06/26/06	06/30/08	140,000	280,000
06086	West Virginia University	Perform Emissions Testing of up to Four Cleaire Longview Systems on Waste Collection Vehicles	01/17/07	04/30/09	180,000	180,000
07020	California Air Resources Board	Analysis of Liquefied Petroleum Gas Samples	08/30/06	04/30/07	10,000	20,000
07054	West Virginia University	Conduct In-Use Emissions Testing of Refuse Trucks	12/13/06	05/31/08	740,000	740,000
07341	Southwest Research Institute	Remote Sensing of Heavy-Duty Engines	06/29/07	12/31/07	70,000	140,000
08033-2	California Air Resources Board	Test Particulate Measurement Device for In-Use Vehicles	06/25/07	06/24/10	125,000	504,514

**Emission Control Technologies**

01173	National Renewable Energy Lab	Advanced Diesel Fuels, Engines, NOx Absorber Catalyst & Diesel Particulate Filter Project for Heavy-Duty Engine Application	06/11/01	08/31/08	260,000	1,920,435
07236	National Renewable Energy Laboratory	Investigate the Role of Lubricating Oil on Particulate Matter Emissions from Vehicles	03/23/07	08/31/08	200,000	446,887
08033-3	California Air Resources Board	Demonstrate Retrofit SCR System for NOx Emission Reduction Using Crystalline Matrix Storage for Ammonia	06/25/07	06/24/10	78,500	338,268
08068	Johnson Matthey Inc.	Develop & Demonstrate SCR Technology for NOx and PM Emissions	12/14/07	01/31/09	254,000	731,500
08161	Engine, Fuel & Emissions Engineering, Inc.	Demonstrate NOx & PM Emissions Control on Construction Equipment	12/31/07	02/28/09	135,830	330,850

Contract	Contractor	Project Title	Start Term	End Term	AQMD \$	Project Total \$
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**Electric/Hybrid Technologies (cont'd)**

99109	Toyota Motor Credit Corporation	Three-Year Lease of One RAV4 Electric Vehicle	04/04/99	01/01/08	85,277	85,277
04019	University of California, Davis	Optimize & Demonstrate Plug-In Hybrid Electric Vehicles	04/27/04	01/31/08	150,000	458,000
04032	Electric Power Research Institute	Develop, Demonstrate & Evaluate Plug-In Hybrid-Electric Vans in Fleet Use	11/14/03	03/31/10	475,000	1,525,000
05260	Energy Control Systems Engineering, Inc.	Conversion of Light-Duty Vehicle to Plug-In Hybrid Vehicles	09/09/05	10/03/08	260,000	985,000
06182	ISE Research Corporation	Develop & Demonstrate a Natural Gas Hybrid-Electric Transit Bus	08/25/06	08/31/08	300,000	1,050,000
07265	Descanso Gardens	Demonstrate Electric Tram	04/20/07	07/19/08	96,000	121,000
07293	Balqon Corporation	Develop & Demonstrate Electric Tow Tractor for Transportation Containers from Shipping Terminals	04/27/07	05/31/08	527,000	527,000
08063	Quantum Fuel Systems Technologies Worldwide, Inc.	Develop & Demonstrate 20 Plug-In Hybrid Electric Vehicles	12/31/07	12/15/14	2,095,613	2,815,266
08067	Calstart	Demonstrate Hydraulic-Hybrid Shuttle Bus	10/30/07	03/31/10	250,000	1,210,000

**Engine Technologies**

05067	Cummins Inc.	Emission Control System in Low-Sulfur Diesel-Fueled Heavy-Duty Engines	03/09/05	01/31/08	700,000	4,400,000
05196	West Virginia University Research Corporation	Demonstrate & Evaluate an Advanced Diesel Emission Control System in Diesel-Fueled Heavy-Duty Engines	08/13/05	02/28/08	300,000	750,000
05244	Cummins Westport, Inc.	Develop, Demonstrate & Certify Heavy-Duty Natural Gas Engine to Meet 2010 Emission Standards	08/26/05	01/31/08	1,390,000	5,943,410
07306	Emission Solutions, Inc.	Develop, Demonstrate & Certify Heavy-Duty Natural Gas Engine Meeting 2010 Emission Standards	06/28/07	07/31/08	400,000	1,200,000

**Hydrogen Technologies and Infrastructure**

03201	University of California, Irvine	Develop & Demonstrate Hydrogen Fueling Stations in Orange County	10/16/03	11/30/09	863,400	983,400
04009	Energy Conversion Devices, Inc.	Integrate & Develop an ICE Hybrid Vehicle Utilizing Metal Hydrides for On-Board Hydrogen Storage	03/12/04	01/12/08	200,280	400,561
04011	Air Products and Chemicals, Inc.	Install & Demonstrate an Industrial Pipeline-Supplied Hydrogen Fueling Station in Torrance	08/03/05	04/02/08	400,000	855,710
04111	Stuart Energy	Maintenance & Data Management for the SCAQMD Hydrogen Fueling Station	02/16/05	02/16/09	80,000	80,000
04185	Quantum Fuel Systems Technologies Worldwide	Develop & Demonstrate Hydrogen Internal Combustion Engine Vehicles	10/18/04	08/31/10	2,109,851	3,505,631



Contract	Contractor	Project Title	Start Term	End Term	AQMD \$	Project Total \$
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**Hydrogen Technologies and Infrastructure (cont'd)**

05165	Air Products and Chemicals Inc.	Install & Demonstrate Three Electrolyzers (in Burbank, Riverside & Santa Monica) and Two Mobile Fuelers (in Santa Ana & Ontario), with One Year of Hydrogen Fuel Supply	06/21/05	03/01/08	2,982,000	2,982,000
06209	City Engines Inc.	Develop & Demonstrate Heavy-Duty Hydrogen and Natural Gas Mixture Engine	08/30/06	08/30/08	500,000	1,000,000
07033	SunLine Transit Agency	Expand Reformer System & Upgrade Fueling Station in Coachella Valley	10/19/06	03/31/08	640,000	1,200,000

**Mobile Fuel Cell Technologies**

04003	DaimlerChrysler RTNA, Inc.	Install/Demonstrate Fuel Cell Vehicle Maintenance Facilities in Long Beach	11/21/05	05/21/08	253,000	542,000
04004	Mercedes-Benz USA, LLC	Demonstrate Two Fuel Cell Vehicles at SCAQMD in Diamond Bar	02/04/05	06/04/08	240,000	1,240,000
04126	American Honda Motor Company	Lease of One Additional Honda Fuel Cell Electric Vehicle	06/22/04	05/23/08	49,795	49,795
05104	Alliance Power Inc.	Stationary Fuel Cell Demonstration in South Coast Air Basin	07/28/05	03/27/08	565,000	4,176,325
05122	Plug Power Inc.	Demonstrate 3 PEM Stationary Fuel Cells in South Coast Air Basin	03/14/05	07/31/09	257,500	572,604
07356	ISE Research Corporation	Upgrade & Demonstrate Fuel Cell Bus	11/02/07	08/31/09	325,000	1,275,000

**Health Impacts Studies**

05037	California Air Resources Board	Enhanced Exposure Assessment of Health Effects of PM	06/28/04	05/31/08	501,814	4,392,814
07181	California Air Resources Board	Physical, Chemical & Toxicological Assessment of the Semi-Volatile & Non-Volatile Fraction of PM	01/17/07	04/01/10	338,975	677,950
07196	California Air Resources Board	Environmental Justice Saturation Monitoring of Selected Pollutants in Wilmington	01/17/07	12/31/08	100,000	400,000
07359	University of Southern California	Study on Combustion Exhaust and Respiratory Health of Port Community Children	12/14/07	08/31/08	489,300	2,989,300
08033-4	California Air Resources Board	Spatiotemporal Analysis of Air Pollution and Mortality in California Based on the American Cancer Society Cohort	06/25/07	06/24/10	374,988	749,976
08033-5	California Air Resources Board	Extended Analyses of Air Pollution & Cardiopulmonary Disease in the California Teachers Study Cohort	06/25/07	06/24/10	142,326	284,652

**Stationary Clean Fuels Technology**

99046	Engelhard Corporation	Field Evaluation of PremAir Ozone Catalyst Technology on AC Units	10/06/98	12/31/10	0	0
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Contract	Contractor	Project Title	Start Term	End Term	AQMD \$	Project Total \$
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**Stationary Clean Fuels Technology (cont'd)**

03292	Occidental College	Professional Wet Cleaning Technology Demonstration & Pilot Incentive Program	06/23/03	12/31/08	16,000	391,000
05207	SolSource Energy	Install an 80 kW Solar Panel System at SCAQMD Headquarters	06/06/05	06/05/11	360,000	693,000
06071	Gas Technology Institute	Field Demonstration of Advance Technology Boiler in South Coast District	03/15/06	12/15/08	135,000	612,146
07017	Gas Technology Institute	Field Demonstration of 5-PPM FIR Ultra-Low NOx Burner on a Watertube Boiler	10/19/06	07/16/08	90,000	300,000

**Outreach and Technology Transfer**

97110	Burke, Andrew F.	Review & Assessment of Technical Proposals Regarding ATTB Ultracapacitor System	06/04/97	08/31/08	15,000	15,000
97113	JME Inc.	Review & Assessment of Technical Proposals Regarding ATTB Ultracapacitor System	05/08/97	03/31/09	15,000	30,000
00069	Walsh Consulting	Technical Assistance Relating to the Use of Alternative Fuels in Mobile Sources	02/17/00	02/28/08	20,000	20,000
02114	Gladstein, Neandross & Associates LLC	Outreach Support of Low-Emission Clean Fuel Heavy-Duty Vehicles	02/22/02	02/28/08	250,000	250,000
02295	Synchroenergies Inc.	Technical Assistance on Lubricants, Fuels, Combustion, Alternative Energy Sources, & High Performance Fluid Technologies	05/23/02	06/30/09	25,000	25,000
02308	Sperry Capital, Inc.	Evaluate Financial Stability of Potential Contractors	06/25/02	12/31/09	20,000	20,000
02311	Cole, Jerald A.	Technical Assistance for Development, Outreach, & Commercialization of H2 Infrastructure & Reforming Technology	08/09/02	06/30/09	30,000	30,000
02333	University of California, Riverside	Technical Assistance on Clean Fuels, Hydrogen, Fuel Cell & Natural Gas Technologies	11/01/02	06/30/09	30,000	30,000
02335	Neil C. Otto	Technical Assistance on Fuel Cell Technology	08/09/02	06/30/09	30,000	30,000
04049	Engine, Fuel & Emissions Engineering Inc.	Technical Assistance for Alternative Fuels Engine Technology	11/21/03	04/30/09	60,000	60,000
04053	Marathon Technical Services	Technical Assistance for Alternative Fuels Infrastructure	11/21/03	12/31/09	40,000	40,000
04097	Calstart	Ongoing Operation & Improved Functionality of Clean Car Maps Internet Website	06/15/04	03/31/08	110,000	355,000

<b>Contract</b>	<b>Contractor</b>	<b>Project Title</b>	<b>Start Term</b>	<b>End Term</b>	<b>AQMD \$</b>	<b>Project Total \$</b>
<b>Outreach and Technology Transfer (cont'd)</b>						
04146	Tom Gross	Technical Assistance for Hydrogen & Fuel Cell Technologies	06/23/04	05/31/09	25,000	25,000
05008	Bevilacqua-Knight Inc.	Participate in California Fuel Cell Partnership for CY 2006 & Provide Support for Regional Coordinator	07/07/04	07/06/08	535,200	2,361,400
05101	Joseph Calhoun	Technical Assistance for Development, Outreach & Commercialization of Advanced Low-Emission Vehicle Technologies	01/07/05	01/31/08	40,000	40,000
05121	Sullivan, Cindy	Development, Analysis & Technology Implementation of Incentive Programs	03/14/05	03/31/09	75,000	75,000
05126	St. Croix Research	Development, Outreach & Commercialization of LNG, CNG and Hydrogen Fuels	03/15/05	03/31/09	25,000	25,000
05127	Protium Energy Technologies	Development, Outreach & Commercialization of Hydrogen and Fuel Cell Technologies	03/14/05	03/31/08	60,000	60,000
05128	Mid-Atlantic Research Institute LLC	Development, Outreach & Commercialization of Advanced Heavy-Duty and Off-Road Technologies	08/08/05	03/31/09	40,000	40,000
05171	James Hazelton	Technical Assistance on AB 1222 Advisory Group	04/08/05	03/31/08	45,000	45,000
05198	Don Stedman	Technical Assistance for Remote Sensing Programs for Light-Duty Vehicles and Locomotives	05/30/05	11/30/08	25,000	25,000
06147	A 2nd Opinion, Inc.	Consulting Services in Preparation of Mobile Source Emissions Element of 2007 AQMP	05/12/06	03/31/08	75,000	75,000
06161	Saint Malo Solutions	Consulting Services in Preparation of Mobile Source Emissions Element of 2007 AQMP	05/17/06	03/31/08	115,000	115,000
06173	Maria Robles	Administrative Assistance Services Related to Organization of International Conferences on Asthma and Port Emissions Control Technologies	05/12/06	08/31/08	125,000	125,000
07012	TIAX, LLC	Technical Assistance Related to the Air Quality Impact of Fuel Ethanol Usage	09/15/06	08/31/08	100,000	100,000
07027	Engine, Fuel & Emissions Engineering Inc.	Technical Assistance for Air Quality Impacts & Mitigation	09/29/06	08/31/08	25,000	25,000
07028	TIAX, LLC	Technical Assistance for Air Quality Impacts & Mitigation of Regional Goods Movement	09/21/06	08/31/08	50,000	50,000
07044	Chery Cooper	Technical Assistance to Perform Web Editor Functions	09/22/06	03/21/08	2,901	2,901
07059	Dowling Associates, Inc.	Technical Assistance Related to Air Quality Impacts of Regional Goods	12/19/06	11/30/08	68,000	68,000

<b>Contract</b>	<b>Contractor</b>	<b>Project Title</b>	<b>Start Term</b>	<b>End Term</b>	<b>AQMD \$</b>	<b>Project Total \$</b>
<b>Outreach and Technology Transfer (cont'd)</b>						
07060	Don Breazeale and Associates, Inc.	Technical Assistance Related to Air Quality Impacts of Regional Goods Movement	11/15/06	11/30/08	58,000	58,000
07062	The Tioga Group, Inc.	Technical Assistance Related to Air Quality Impacts of Regional Goods	12/19/06	11/30/08	58,000	58,000
07129	Breakthrough Technologies Institute, Inc.	Technical Assistance with Fuel Cell Technology	12/01/06	03/31/08	40,000	40,000
07130	Burnett & Burnette	Technical Assistance with CNG Technology	01/17/07	12/31/08	40,000	40,000
07185	Joseph C. Calhoun, P.E., Inc.	Technical Assistance for Development, Outreach & Commercialization of Advanced Low-Emission Vehicle Technologies	01/29/07	01/31/08	20,000	20,000
07247	TIAX LLC	Technical Assistance with Low-Emission and Alternative Fuels Technologies	03/19/07	12/31/08	50,000	50,000
07314	Engine, Fuel & Emissions Engineering, Inc.	Technical Assistance with Advanced Heavy-Duty and Off-Road Technologies	06/25/07	12/31/09	60,000	60,000
07342	Douglas R. Lawson	Technical Assistance for Mobile Source Technologies	06/21/07	08/31/08	15,000	15,000
07360	Gladstein, Neandross & Associates LLC	Host the Southern California Clean Vehicle Technology Expo	06/29/07	01/31/08	37,973	37,973
08053	Electric Drive Transportation Association	Cosponsor EVS-23: Sustainability – The Future of Transportation Electric Vehicle Symposium	10/09/07	02/28/08	40,000	40,000

## **Appendix C**

### **Final Reports for 2007**



## Install CNG Refueling Facility in Downey

### Contractor

R.F. Dickson Company, Inc. dba California Clean Fuels

### Cosponsors

California Energy Commission  
South Coast Air Quality Management District  
City of Bellflower  
City of Lakewood  
California Clean Fuels

### Project Officer

Larry Watkins

### Background

California Clean Fuels (CCF) supports the goal of clean air and a healthier environment through the reduction of air pollution from motor vehicles. The upgraded station greatly improves fueling support to the growing fleet of regionally operated light-, medium-, and heavy-duty compressed natural gas (CNG) vehicles. School districts, transit fleets, and waste collection operators continue to implement fleet conversion to CNG to meet local SCAQMD and California Air Resources Board (ARB) fleet rules and regulations. This station specifically supports R. F. Dickson's growing fleet of CNG heavy-duty municipal street sweepers as well as Bellflower Unified School District's (Bellflower USD) CNG school buses and maintenance fleet vehicles.

### Project Objective

The objective of this project was implementation of a CNG fueling station to support CNG street sweepers and local school district and city fleets. Once the station was commissioned, it quickly became apparent that additional capability was needed to support the growing CNG fleet in the region. CCF immediately began the process of soliciting grant support to implement a station upgrade that: 1) helped the station to better meet projected throughput requirements as a function of peak demand over time, 2) met long-term operational requirements, 3) was designed using state-of-the-art, proven fuel storage, dispensing and

compression technologies, 4) is easy to access and operate by a variety of NGV configurations, and 5) is compatible with all applicable codes and standards to ensure safe installation and operation.

### Technology Description

Under this grant agreement, California Clean Fuels commissioned a regional CNG fueling station, which is strategically located at 15330 South Woodruff Avenue, Bellflower, CA 90706. This station is near the 91, 5, 605, 710, and 105 freeways, providing excellent public access for the CNG vehicle population operating throughout southern California.

Equipment specifications that met key project criteria were used to solicit an experienced CNG station contractor. The station prime contractor selected was Weaver Construction. CCF continues to operate and maintain the station. The station and subsequent station upgrade meet all applicable codes/standards for CNG fueling. Steve Dickson was responsible for overall project management to ensure the timely completion of the project.

### Status

The original station opened on October 20, 2002 and operated according to expectations. The expanded station opened on May 15, 2007. CCF experienced a handful of startup "bugs", including computer software problems. All hardware issues have now been addressed, but the software issues continue to need attention. Fleet customers of the



expanded station include the City of Bellflower, the City of Lakewood, R.F. Dickson Company, Inc. (street sweepers), Bellflower USD, Super Shuttle and Express Shuttle, among many others. The station is equipped with a universal card billing system that allows the use of standard Visa/MasterCard-type credit cards.

## Results

The completed station upgrade provides a significant improvement in our ability to service increasing numbers of large fleet vehicles in a timely and convenient manner, consistent with preferred fleet operations. The original station configuration included the following key elements:

- A compressor with compression capacity of 260 scfm.
- 72,000 scf of compressed gas storage.
- A dual-hose fuel dispenser.

The upgrade included the following key elements:

- An additional compressor that increased compression capacity from the previous capacity of 260 scfm to 920 scfm. This additional fuel compressor facilitates movement of more, and larger, vehicles through the station in a timely manner.
- Three additional ASME compressed gas storage vessels, increasing storage from 72,000 to 108,000 scf. This increased storage allows for a significant increase in the number of vehicles that can now be fueled at peak times.
- An added fuel dispenser, integrated in a manner to ensure that larger vehicles may be easily accommodated at this new dispenser. This dispenser is equipped with both a standard NGV1 nozzle and a high flow transit fleet customer base. The dispenser also includes a credit card system for user-friendly public access.

Prior to the upgrade, the station dispensed an average of 53,348 GGE over a two-month period. Over the next two months (after the upgrade was online), a total of 62,275 GGE were dispensed from the station, though there have been a few initial start-up problems with the station, adversely affecting throughput. Once all of the upgraded station's operational bugs are fully addressed, CCF anticipates that throughput will grow to an annual

average of 400,000 GGE within the next three years.

## Benefits

The use of low-emission CNG-fueled vehicles and refueling stations is an effective strategy to reduce mobile source emissions and reduce consumption of foreign oil imports. The original planned throughput load at the station was 224,000 GGE per year. The recently completed station upgrade is projected to increase this throughput load to 400,000 GGE per year. Each equivalent gallon of CNG dispensed equates to varying degrees of NOx and diesel PM emissions reductions, depending on the age and usage of the CNG vehicles and the diesel vehicles they replace. Some sources also project that CNG vehicles reduce greenhouse gases by up to 20 percent, as compared to petroleum-fueled vehicles.

## Project Costs

The AQMD contributed co-funding in the amount of \$211,148 towards this project. California Clean Fuels and its partners contributed \$501,247 towards the CNG station expansion for a total cost of \$712,395 to date. Projected costs were originally \$703,828. Cost increases were a result of the extended amount of time required to execute a contract with project partner CEC. In the added time to initiate the project, costs of raw materials increased dramatically. Please refer to Table 1 in the Final Report for a detailed breakdown of planned versus actual costs.

## Commercialization and Applications

The use of low-emission alternative fuel vehicles and refueling stations is an effective strategy to reduce mobile source emissions. The purchase of alternative fuel vehicles and construction/expansion of CNG stations is replicable by local agencies and private fleets throughout the SCAQMD's operational jurisdiction and beyond.



## Demonstrate Low-Emission, Alternative-Fuel Heavy-Duty Vehicles within SCAB & Conduct Public Awareness Program

### Contractor

Gladstein, Neandross & Associates LLC (GNA)

### Cosponsors

49 public and private agencies

### Project Officer

Connie Day

### Background

Since 1996, the SCAQMD has supported the Interstate Clean Transportation Corridor (ICTC), a public-private partnership to link Sacramento/Los Angeles, Las Vegas, and Salt Lake City in a triangle of clean-fuel infrastructure loop that supported clean vehicle deployments. In addition, the AQMD has funded targeted workshops to educate fleet operators about alternative-fuel vehicles in order to accelerate air quality improvements and reduce dependence on foreign sources of petroleum.

The following objectives are met through the deployment of heavy-duty, alternative-fuel vehicles:

- The AQMD Fleet Rules (1190 Series), California Air Resources Board (ARB) Diesel Risk Reduction Plan.
- California Energy Commission (Energy Commission) Strategy for Reducing Petroleum Dependency in California and California Alternative Fuels Plan (AB 1076 and AB 1007).
- U.S. Environmental Protection Agency (EPA) West Coast Collaborative to Reduce Diesel Emissions.
- San Pedro Bay Ports Clean Air Action Plan (CAAP).

These vehicles provide an economically and operationally feasible strategy for reducing NO<sub>x</sub>, PM, and GHG emissions, while at the same time displacing use of gasoline and diesel.

### Project Objective

In May 2004, the AQMD executed a contract with GNA for \$125,000 to accelerate market penetration of low-emission, alternative-fuel, heavy-duty vehicles. The AQMD issued three task orders: 1) to support the ICTC (\$60,000); 2) conduct a Clean Vehicle Expo (\$55,000); 3) and support Proposition 1B efforts (\$10,000).

The goals for the ICTC support were to develop 25 natural gas fueling stations and deploy 600 low-emission, heavy-duty vehicles. The ICTC projected that these actions would reduce NO<sub>x</sub> by 500 tons per year, displace 4.5 million gallons of diesel annually, and generate \$75 million in economic activity.



The Southern California Clean Vehicle Expo (EXPO) was envisioned as a two-day event that would provide information to fleet operators and purchasing decision makers about alternative-fuel vehicles and other low-emission and vehicle technologies. The EXPO aimed to educate attendees about product availability, funding opportunities, and the fleet rules. The final task order sought to ensure that an equitable proportion

of the Proposition 1B funding is allocated to the region.

**Technology Description**

The project was effective in accelerating the replacement of higher-polluting heavy-duty diesel vehicles with alternative-fuel technologies.

Through the ICTC and EXPO, the project has encouraged communication among manufacturers, station developers, fuel providers, funding agencies, and fleets. The ICTC has encouraged the clean technology market by developing a natural gas refueling infrastructure to support the deployment of low-emission vehicles. The ICTC initially focused on return-to-base fleets with high fuel throughputs, since these projects were the most economically viable. These success stories were then promoted, as fleets shared their experiences with other parties interested in developing product or developing projects.

**Status**

The contract term commenced May 2004 and ended December 2007. The ICTC continues to expand alternative-fuel infrastructure and the deployment of clean, heavy-duty vehicles with funding and support from various Steering Committee member agencies including: Antelope Valley AQMD, Mojave Desert AQMD, and San Bernardino Associated Governments. The EXPO project final report, which detailed event highlights, exhibitors, press coverage, survey results, and budget, was presented to the SCAQMD in October 2006.

**Results**

During the project period, unprecedented progress was made toward the reduction of mobile source emissions. The ICTC and EXPO helped accelerate market penetration of alternative-fuel vehicles, while the emission performance of these vehicles reinforced the ability for this technology to achieve the goals of the SCAQMD.

Natural gas technologies provide the cleanest available internal combustion engines. Heavy-duty engines for model years 2003 through 2006 were required to meet a NOx standard of 2.5 g/bhp-hr NOx plus NMHC. During that time, no diesel engine was certified to meet the Optional Low NOx standard of 1.8 g/bhp-hr NOx and NMHC. However, 18 natural gas engines were certified at

this low-emission level. Although diesel engines further decreased their emissions to 1.2 g/bhp-hr NOx in 2007, heavy-duty natural gas engines now meet the extremely low-emission 2010 on-road standard of 0.2 g/bhp-hr.

**Benefits**

Since its inception in January 1996, the ICTC Project has been the nation’s most successful public/private partnership dedicated to accelerating the market penetration of clean, alternative-fuel vehicles in interstate goods movement. At present, ICTC staff has helped to secure \$28.9 million in funding to:

- Build 23 natural gas fueling stations.
- Deploy 505 heavy-duty and 160 light-duty natural gas and LPG vehicles to utilize this AFV infrastructure.
- Reduce diesel consumption by approximately 6.8 million gallons annually.
- Reduce emissions of priority pollutants (NOx and PM) by 380 tons annually.
- Generate \$89 million in economic activity.

Over 550 of Southern California’s public and private fleet vehicle operators attended the EXPO, held at the Ontario Convention Center on October 10-11, 2006. The EXPO included two days of expert panels discussing the latest vehicles, technologies, and funding opportunities. The event’s Ride & Drive also featured over 23 vehicles, ranging from transit buses to school buses to street sweepers, and included many light-duty vehicles operating on hydrogen, natural gas, propane, electric and plug-in hybrid technologies.

**Project Costs**

GNA leveraged \$4.27 from 49 other public/private sources for every \$1.00 invested by the SCAQMD. The cost share secured, as detailed below, exceeded the cost-share commitment by \$84,250.

Task	SCAQMD	Cost Share	Total
Task 1: ICTC	\$ 60,000	\$309,999	\$359,999
Task 2: Expo	\$ 55,000	\$223,250	\$278,250
Task 3: Prop. 1B	\$ 10,000	\$	\$ 10,000
<b>TOTAL</b>	<b>\$125,000</b>	<b>\$533,249</b>	<b>\$658,249</b>

### **Commercialization and Applications**

Since the 2004 federal engine standards came into effect in October 2002, the availability of heavy-duty natural gas engines declined. However, the SCAQMD's investment in successful alternative-fuel projects has led to increased regional demand for cleaner, alternative-fuel products and increased throughput of alternative fuels within the region. These clean trucks, buses, and other engines are now in use throughout the jurisdiction of the SCAQMD, and these successes are now spurring some renewed market development. Consumer education about gasoline and diesel prices, alternative fuels, emission regulations, and grant/tax incentives will continue to be important to expanding the deployment of heavy-duty alternative-fuel vehicles. By continuing to support the evolving ICTC in conjunction with the EXPO, the SCAQMD has the perfect mechanism to continue efforts to meet its clean air goals.

## Update & Expand School Bus Inventory in the Basin

### Contractor

Burnett & Burnette

### Cosponsors

N/A

### Project Officer

Ranji George

### Background

In 2000-2001, SCAQMD had undertaken a school bus survey that identified approximately 140 school districts with about 8,600 school buses in SCAQMD jurisdiction, i.e. in the counties of Los Angeles, Orange, Riverside, and San Bernardino. Since the survey, about 46 districts operated CNG buses.

As there have been several purchases and retirements of school buses since the first survey, there was a need to update and expand this inventory to facilitate future planning. Program Announcement Number PA2006-05, dated October 26, 2005, was issued to solicit contractor bids to update the six-year old survey. Burnett and Burnette (B&B) was selected and awarded the contract to update and expand the school bus survey.

### Project Objective

The B&B contract identified five specific tasks as project objectives:

- Task 1: Review Existing Databases and Design Survey
- Task2: Site Visits
- Task 3: Data Management and Packaging
- Task 4: Training and Warranty
- Task 5: Reporting and Deliverables (including master Excel and Access database for the entire school bus fleet for Public/Private/Fleet Contractors)

### Tasks Completed

B&B used the following strategies and methodologies to complete the project tasks:

- Reviewed the existing SCAQMD databases and obtained the California Department of Education database to compile a list of all public, private, and contractor fleets as well as facility locations and contact names.
- Designed detailed survey spreadsheets to collect information from the fleets for buses, fueling stations, and repair garages.
- Completed 10 demonstration sites with 1,750 buses using the new survey spreadsheets.
- Completed spreadsheet upgrades based on the demo and meetings with SCAQMD staff and mailed to 136 public/private/fleet contractors.
- Emailed/telephoned all 136 fleets to confirm receipt and check bus inventory counts.
- Offered site visits to fleets with more than 15 buses.
- Received 88 surveys from responding fleets and resolved compatibility issues.
- Packaged all data into the Master Excel and Access databases. Excel and Master databases consist of buses, garages, and fuel garages for public, private, and contractor fleets.
- Met with SCAQMD staff to analyze and discuss the submitted data from the fleets for final database compatibility and consistency.
- Issued Final Reports and Master spreadsheets and databases in Excel and Access formats for all fleets that participated in survey.
- Created custom software that queries the Master Access database to create over 20 various reports.

**Status**

The project is now complete.

**Results**

Ten (10) demonstration sites totaling 1,750 (or 20% of the estimated total) buses at public schools and fleet contractors were completed in May 2006.

Thirty-six (36) sites accepted a site visit, and site visits were completed between May and October 2006. During the site visit, information was provided to the fleets regarding potential compressed natural gas (CNG) fueling stations and garage modifications.

The chart below shows the fleets included in the survey.

TYPE OF FLEET	# OF FLEETS IN SURVEY	COMPLETED SURVEY	REMAINING
PUBLIC	90	72	18
PRIVATE	9	3	6
CONTRACTOR	17	8	9
<b>TOTAL</b>	<b>116</b>	<b>83</b>	<b>33</b>

\* 10 out of 18 Public; 6 out of 6 Private Schools; and 5 out of 9 Contractors fleets have less than 15 buses.

The chart below describes the fleets and number of buses included in the survey.

TYPE OF FLEET	# OF BUSES IN SURVEY	COMPLETED SURVEY	NO SURVEY
PUBLIC	4,528	4,262	305
PRIVATE	91	46	45
CONTRACTOR	5,918	5,755	164
<b>TOTAL</b>	<b>10,537</b>	<b>10,063</b>	<b>514</b>

As shown below, there are 53 public school fleets that contract to fleet contractors or other school districts.

PUBLIC SCHOOL DISTRICTS THAT SUBCONTRACT SERVICE			
COUNTY	FLEET CONTRACTORS	OTHER PUBLIC SCHOOL DISTRICTS	TOTAL
LA	33	3	36
ORANGE	5	0	5
RIVERSIDE	5	1	6
SAN BERNARDINO	5	1	6
<b>TOTAL</b>	<b>48</b>	<b>5</b>	<b>53</b>

Survey results are a snapshot of the bus inventory as of September 30, 2006, and before SCAQMD awards in 2006 came into effect. In 2006, SCAQMD awarded 148 new CNG buses to replace diesel buses: 132 pre-1986 buses and 16 pre-1977 buses.

The following chart shows the breakdown of each fleet type by age.

SCHOOL DISTRICTS, CONTRACTORS & PRIVATE SCHOOLS	Total Buses	SCHOOL BUSES MODEL YEAR			
		1994 & Newer	1987 to 1993	1977 to 1986	1976 & Older
CONTRACTOR	5,755	5,334	351	69	1
PRIVATE	46	32	13	1	0
PUBLIC	4,262	2,113	967	1,105	35
<b>Total</b>	<b>10,063</b>	<b>7479</b>	<b>1331</b>	<b>1175</b>	<b>36</b>

The chart below shows the breakdown of each county by fuel type.

COUNTY	Total		SCHOOL BUSES BY FUEL TYPE			
	with < 15 Buses	with ≥ 15 Buses	Total	Gasoline	Diesel	CNG
LOS ANGELES	5	28	5,752	185	5,315	253
ORANGE	3	17	1,415	167	1,202	46
RIVERSIDE	3	14	1,391	134	1,098	159
SAN BERNARDINO	1	15	1,505	43	1,379	83
<b>Total</b>	<b>12</b>	<b>74</b>	<b>10,063</b>	<b>529</b>	<b>8,994</b>	<b>541</b>

The chart below describes fleet inventory by fuel type.

SCHOOL DISTRICTS, CONTRACTORS & PRIVATE SCHOOLS	Total		SCHOOL BUSES BY FUEL TYPE			
	with < 15 Buses	with ≥ 15 Buses	Total	Gasoline	Diesel	CNG
CONTRACTOR	2	7	5,755	129	5,578	48
PRIVATE	1	2	46	3	43	0
PUBLIC	7	59	4,262	397	3,373	493
<b>Total</b>	<b>10</b>	<b>68</b>	<b>10,063</b>	<b>529</b>	<b>8,994</b>	<b>541</b>

**Benefits**

With the new survey, the SCAQMD can accurately identify old diesel school bus inventories that are eligible for replacement or retrofit with PM traps. Grant applications can be evaluated more effectively with fleet information from potential grantees. Also, in an effort to reach its clean air goals, SCAQMD can determine which school districts have the cleanest buses and are protecting the health of its school children. SCAQMD can then target its future funds to school districts with a disproportionate number of old school buses.

**Project Costs**

B&B received \$50,000 to complete this contract.

**Commercialization and Applications**

The SCAQMD's Lower Emission School Bus Program seeks to identify and replace the oldest diesel school buses in the Basin or retrofit newer buses with PM traps. The information obtained in

the survey facilitates implementation of the program and results in reducing PM and GHG emissions, both of which are needed to achieve clean air goals.

AQMD Contract #07003

December 2007

## Install a CNG Refueling Facility for School District

### Contractor

Fontana Unified School District

### Cosponsors

N/A

### Project Officer

Ranji George

### Background

School buses provide our nation's children with safe, convenient transportation. Diesel exhaust from school buses, however, poses a health risk, particularly to children. Diesel exhaust also exacerbates lung diseases such as asthma and emphysema. Natural gas is an inherently cleaner alternative fuel that produces very low particulate and nitrogen dioxide emissions. Utilizing natural gas fuel not only provides greater overall emission reductions, but also supports the goals of fuel diversity and reduces petroleum dependence.

### Project Objective

The Compressed Natural Gas (CNG) Refueling Station is located at 9820 Citrus Avenue in Fontana. In the current configuration, it is capable of providing the refueling needs of almost 14 school buses with time-filling of compressed natural gas at 3,600 psi. The project has been designed to meet the future demands up to year 2018 (35 school buses) with all civil/mechanical/electrical infrastructure currently installed. Future expansion will only require the addition of supplemental compression equipment and fueling posts.

### Technology Description

Natural gas, in the form of CNG, has been used as a transportation fuel in vehicles for more than 60 years around the world. Comprising about 95% methane, its clean burning properties, abundant supply, and relatively low cost have made it a popular and environmentally sensitive fuel choice for drivers in Europe, Russia, South America,

Australia and New Zealand, and the United States, and Canada. There are over 1 million Natural Gas Vehicles (NGVs) on the road worldwide with thousands of public, fast-fill refueling stations to support them. The CNG refueling station for Fontana USD consisted of the following components:

- 2 Angi International CNG-75 compressors.
- 1 Xebec STR24NGX-2-Autodew gas dryer.
- 1 time-fill panel and buffer bottle.
- 4 k-rail mounted dual hose time-fill posts.



The natural gas dryer is a skid-mounted, automatic, regenerative, single-tower dehydrator specifically designed for drying pipeline natural gas before being processed for use as a motor fuel. The dryer was sized for a flow rate of 300 scfm, which is adequately designed for the future expansion of the facility.

The 50 Hp electric drive compressors have an output of 75 scfm (standard cubic feet per minute) to give a combined output of approximately 70 DGE (diesel gallon equivalents) per hour. The compressors and controls are contained inside a weatherproof enclosure, which limits the maximum noise to 75 dBA at 10 feet from the equipment.

The time-fill posts are k-rail mounted and consist of 15-foot long, 3/8-inch diameter 5,000 psi AGA-

certified hoses, each with a 3,600 psi Sherex NGV-1, type 2 nozzle and appropriate breakaways and retractors. The on-site construction consisted of the installation of a new gas MSA (Meter Set Assembly) by Sempra Utilities, which provided regulated 16 psi natural gas to the gas dryer and compressors by way of an above-ground 2-inch schedule 40 steel supply line. The CNG was then delivered to the time-fill posts (via the time-fill panel) by the use of ½-inch and 3/8-inch stainless steel tubing.

A new 400 amp/480 volt electrical service was installed by Southern California Edison which had been sized for the future expansion.

For safety purposes, the equipment area for the CNG equipment was enclosed by an 8-foot high masonry block wall on two sides and chain link fence and lockable gates on the other two. Fire extinguishers and signage approved by the County Fire Marshall was installed throughout the facility with special attention paid to the location of the ESD (Emergency Shut Down) devices.

The facility is serviced daily by a district mechanic to monitor operations, and there are plans for a more comprehensive service contract in the near future to perform routine maintenance.

### **Status**

The contract for the design/build project was awarded May 15, 2007, and construction began on August 8. No major problems were encountered during construction. However, there were some minor delays associated with providing new, dedicated power and natural gas services to the facility. Fueling of the CNG buses commenced on October 15, and currently the utilization of the station is limited to the use of the District.

### **Results**

Utilizing locally available natural gas from Sempra Energy at 20 psi and a new 460 volt, 200 amp power service from Southern California Edison, this new refueling facility is capable of proving 3,600 psi CNG for almost 14 school buses. The combined output of the two 50 HP, 75 scfm

(standard cubic feet per minute) is approximately 70 DGE. Field output verifies this result.

### **Benefits**

From Maine to California, more than 180 school districts are using NGVs in their fleets every day. This number will increase as these districts build on their successes and new ones join the trend.

NGVs are very clean, providing the greatest emission reductions and related environmental benefits of all available alternatives. They also have an added advantage: they displace petroleum fuel. Reducing dependence on oil has become an ever more-pressing priority as the oil-producing regions of the world become increasingly unstable politically and as oil demand outpaces supply and causes prices at the pump to rise. About 98% of all the natural gas used in the U.S. comes from the continental U.S. and Canada. The environmental and political benefits of using CNG school buses over those of diesel are obvious.

### **Project Costs**

The cost to complete this project was approximately \$450,000.

### **Commercialization and Applications**

Current regional costs for the production of CNG run at approximately \$1.80 per DGE (before \$0.50 motor fuels excise tax credit). Therefore, CNG is currently a commercially viable fuel.



## Optimize & Demonstrate Oxidation Catalysts to Reduce Emissions from CNG Heavy-Duty Vehicles

### Contractor

Engine Control Systems

### Cosponsors

SCAQMD

West Virginia University

Environment Canada

Metropolitan Transportation Authority

Riverside Transit Agency

### Project Officer

Adewale Oshinuga

and to prevent catalyst over-temperature conditions but reduced the injection rate of fuel to the engine. During the prototype engine evaluation program at Environment Canada, the revised engine software and a series of catalyst formulations were tested to ensure engine performance and safety, and to evaluate a series of oxidation catalyst formulations supported on cordierite monoliths with a cell density of 400 cpsi.

### Status

The demonstration portion of the project is now complete. The draft final report preparation is in progress.

### Background

The efforts of public agencies and private industry have resulted in an increased number of vehicles now powered by compressed natural gas (CNG) engines. The vast majority of older heavy-duty CNG engines are not equipped with exhaust emissions control technologies. Recent studies have shown that oxidation catalysts can reduce non-methane hydrocarbons (including toxic hydrocarbons), carbon monoxide, and particulate matter emissions.

### Project Objective

The objective of this study is to optimize and demonstrate oxidation catalyst technology to further reduce exhaust emissions from 2002 and older Detroit Diesel Series 50G CNG engines in operation in local transit agencies.

### Technology Description

The technology employed consisted of three major components: 1) updated engine software, 2) revised exhaust sensors to protect the installed catalyst against fuel-rich excursions, and 3) an oxidation catalyst which was integrated into a converter muffler. The updated engine software and revised exhaust sensors allowed the engine ECM to monitor the exhaust oxygen content and temperature downstream of the oxidation catalyst

### Experimental Setup

A 1997 Series 50G engine and pressure regulators were sourced from Coast Mountain Bus Company in Vancouver, British Columbia. The engine was inspected and received all recommended DDC service updates and was prepared for operation on an engine dynamometer. In addition, select components were upgraded or installed and engine software was updated to allow the same OEM engine features of a 2002 Series 50G engines which employed an oxidation catalyst. These additional features allowed the engine ECM to integrate, monitor, and protect the function of the oxidation catalyst. The upgraded prototype engine was operated over numerous test conditions to ensure performance and safety. Emissions tests were also performed with a series of OEM and experimental catalyst formulations which are compared in Table 1.



**Figure 1. Prototype Engine at Environment Canada**

**Results**

The upgraded 1997 Series 50G engine compared favorably with the emissions certification values of new 2002 Series 50G engine variants as shown in Table 1.

**Table 1. FTP Certification Emissions Values Compared to Prototype Engine**

	CO	NOx	NMHC	TPM
OE Certification Values				
2002 No catalyst	2.07	1.53	0.7	0.006
2002 With catalyst	0.02	2.08		0.006
Prototype Engine				
Engine Out	2.195	2.182	0.191	0.009
OE Ox. Cat.	0.039	2.244	0.134	0.002
Exp. Ox. Cat. 1	0.045	1.947	0.137	0.002
Exp. Ox. Cat. 2	0.054	2.268	0.159	0.000

The Upgrades/Experimental Catalyst 1 combination was implemented in a 1999 Neoplan bus operated by MTA and a 2002 model year bus operated by Riverside Transit Agency and the buses operated over a 12-month demonstration program. Neither bus experienced any unscheduled maintenance due to the upgraded engines during the demonstration.

At the end of the demonstration, the two buses were evaluated on West Virginia University portable chassis dynamometer over the OCTA emissions test cycle and selected steady-state test conditions.



**Figure 2. WVU Portable Chassis Dynamometer**

Table 2 reports the oxidation catalyst performance on regulated and unregulated emissions from the upgraded 2002 urban bus operated by RTA. After one year of durability demonstration, regulated and unregulated toxic and particle emissions were greatly reduced. The only exception was found to be NOx emissions. The noted increase in NOx emissions and fuel economy as well as a reduction in the btu/mile is believed to be the difference in the ECM sensor signals in the presence and absence of the oxidation catalytic converter muffler and exhaust temperature sensor placement. It is believed that with the sensor issue resolved, NOx emissions as well as fuel economy would be comparable with and without the oxidation catalytic converter.

**Table 2. Emissions Change Observed With Oxidation Catalysts**

Emission	Percent Change
Carbon Monoxide (CO)	-100%
Nitrogen Oxides (NOx)*	+19%
Total Hydrocarbons (THC)	-62%
Particulate Matter Mass (PM)	-100%
Carbon Dioxide (CO2)*	-2.5%
Miles/gallon equivalent*	+4.5%
BTU / mile*	-4.5%
Carbonyls	-96%
Polyaromatic Hydrocarbons (PAH)	Reduced to non-detectable levels
Semi-volatile PAH	-56%
Gas Phase PAH	-46%
Nitro PAH	-60%
VOC's	-85%
Particles (hot catalyst)	Reduced by an order of magnitude
Particle (cold catalyst)	No effect

\* believed to be due to exhaust sensor placement differences between tests with and without catalyst.

### **Benefits**

This study showed that regulated CO, THC, NMHC, PM and unregulated emissions of toxic compounds and particles of older in-use CNG-fueled, heavy-duty engines can be significantly reduced by upgrading with oxidation catalysts and revised engine software.

### **Project Costs**

The project is largely completed and is well within the funds allocated for this study.

### **Commercialization and Applications**

The study shows that existing in-use CNG heavy-duty engines can readily benefit from updates in engine software, sensors, and the implementation of oxidation catalysts to those engines where exhaust emissions control technologies were not previously employed.

## Upgrade & Evaluate a Plug-in Hybrid Electric Sedan with Lithium Polymer Batteries

### Contractor

AC Propulsion Inc.

### Cosponsors

SCAQMD

AC Propulsion Inc.

### Project Officer

Lisa Mirisola

### Background

Zero emission vehicles (ZEVs) operate without tailpipe and refueling emissions, but they have not yet been commercialized. Battery-powered ZEVs have limited range, which slows their market acceptance. Plug-in hybrid vehicles (PHEVs) connect to the power grid while parked so they can operate on batteries for local driving and then use a low-emission petroleum-fueled engine for longer trips. This distinguishes them in a fundamental way from the plugless hybrid vehicles currently produced by automakers which rely 100% on gasoline. The low emission capabilities of ULEV and SULEV automobile engines mean that the onboard hybrid generator can generate electricity with very low emissions. The plug-in hybrid can reduce emissions by eliminating many cold starts, and reduce petroleum consumption by substituting grid electricity for petroleum. Battery technology is key to the commercialization of PHEVs.

### Project Objective

The project objective was to upgrade, evaluate, and demonstrate a Li battery in a PHEV. The project vehicle was developed as a PHEV with lead-acid (PbA) under a SCAQMD-sponsored project completed in 2003. Advances in lithium ion (Li) battery technology since then promised to improve PHEV performance by reducing weight and increasing power and energy storage. The improved battery characteristics would, in turn, improve vehicle acceleration, extend ZEV range, improve efficiency, reduce gasoline consumption, and reduce cold starts, thus enhancing both the

environmental and commercial appeal of the PHEV technology.

### Technology Description

A battery and electric drive system allows the PHEV vehicle to operate on battery energy only. The original PbA battery weighed 725 pounds and gave an EV range of 30 miles.

The replacement battery developed and installed under this project increased EV range to 50 miles and reduced weight by 445 pounds.



The new battery is assembled from Kokam SLPB 100216216 Li-polymer cells. Each cell has a capacity of 40 Ah at a nominal voltage of 3.7V. The PHEV pack comprises 96 cells assembled into eight modules of 12 cells each. All cells are connected in series providing nominal pack voltage of 355V.

Battery management is provided by a proprietary AC Propulsion system that monitors voltage and temperature for each cell and prevents cells from operating outside established voltage and temperature limits. Forced-air cooling controls battery temperature.

### Status

Project work was completed December 2006. A final report including complete technical details and

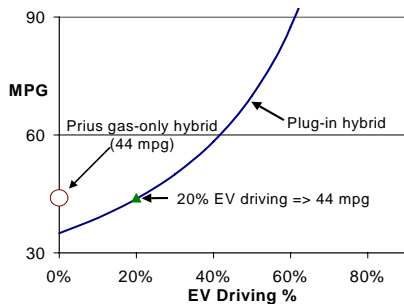
test results was submitted October 2, 2007. The vehicle was driven with the Li battery for the first time in October 2006 and accumulated 1,000 miles within 2 months. It has now accumulated more than 6,000 miles on the Li battery with no battery-related problems.

**Results**

The project vehicle achieves objectives for improved performance, reduced gasoline consumption, and the potential for reduced emissions.

**Performance and Emissions Comparison**

	<b>PHEV Li</b>	<b>PHEV PbA</b>	<b>ICEV Base</b>
Battery lbs	280	725	NA
Vehicle lbs	3235	3680	2885
EV range mi	50	30	0
EV eff wh/mi	190	210	NA
City mpg gas	120	58	23
Hiway mpg gas	34	31	29
0-60 secs	8.0 sec	8.5 sec	12.0
Cold starts/week	2 (est)	8 (est)	16 (est)



The lighter weight of the Li battery contributed greatly to improved performance and efficiency. By substituting electricity for petroleum, the plug-in hybrid can use significantly less gasoline than plugless hybrids.

**Benefits**

The project vehicle demonstrates the potential to reduce emissions by reducing the number of cold starts significantly. Also, by substituting electricity for gasoline, gasoline refueling emissions are reduced. The fuel substitution is also an effective means of reducing petroleum consumption, a stated

goal of U.S. energy policy. The overall air quality and global warming benefits depend on the source of electricity. Plug-in cars can make good use of wind energy, which often peaks at night. Over the longer term, plug-in cars can provide grid support functions by interacting with the grid.

The benefits anticipated for this project have been realized in the demonstration vehicle. Among the benefits are the improvements to the desirable operating characteristics that are necessary for successful commercialization.

**Project Costs**

The project was completed on budget. SCAQMD contributed \$25,300 of the \$53,000 project budget total. Other funding was provided by AC Propulsion’s cost share (\$27,700).

**Commercialization and Applications**

The introduction of the Volt PHEV concept by General Motors at the Detroit Auto Show provided a significant endorsement of the hybrid concepts embodied in the project vehicle. The Volt, proposed for 2010 production, and the Jetta PHEV, originally developed in 2003, share similar architecture and functionality. Both are series hybrids that use internal combustion engines only for electricity generation. Both use front-wheel drive for propulsion, and low, centrally mounted battery packs of about 14 kWh capacity. And both can plug in to the grid and rely exclusively on the battery for all driving until the battery is discharged.

The primary factor that has led GM to embrace this concept is the progress in Li-chemistry batteries that has been achieved since 2003. As this project has demonstrated, Li batteries provide an attractive combination of energy storage, power capability, and low weight. GM’s commitment suggests that Li battery cost, safety, and durability – factors beyond the scope of this project – will be able to meet stringent OEM requirements.

Over the coming decade, substitutes for gasoline will assume increasing importance in the light-duty vehicle segment. The ongoing development of lithium batteries for PHEVs will allow electricity to serve as a viable gasoline substitute.

## Develop & Demonstrate On-Board Diagnostic Systems for Natural Gas Vehicles

### Contractor

Baytech Corporation

### Cosponsors

SCAQMD  
General Motors  
Texas Commission on Environmental Quality  
Clean Energy  
BAF Technologies

### Project Officer

Mike Bogdanoff

### Background

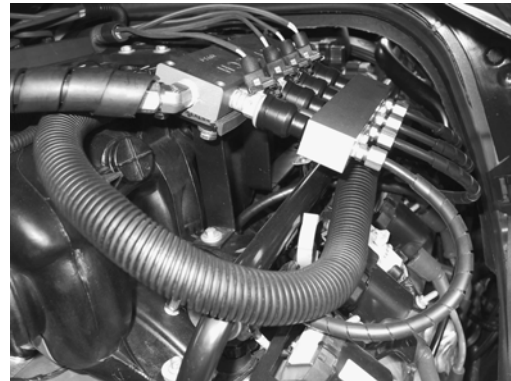
Baytech Corporation is a small volume manufacturer of certified Compressed Natural Gas (CNG) systems for General Motors vehicles and engines. Before 2006, the California Air Resources Board (CARB) granted flexibility to small volume alternative fuel vehicle manufacturers in fully complying with California On-Board Diagnostics II (OBDII) requirements due to significant technological hurdles. Beginning in the 2006 model year, alternative fueled light duty vehicles are required by CARB to demonstrate full compliance with OBDII requirements, as described in Title 13, California Code Regulations Section 1968.2.

### Project Objective

The primary project objective was to develop engine calibrations and perform emissions testing to demonstrate full On-Board Diagnostics II (OBDII) compliance of Baytech's CNG sequential Multi-Port Fuel Injection (MPFI) system, so that Baytech can continue to offer a broad portfolio of CNG vehicles and engines for sale in California. A second project objective was to show how assigned Deterioration Factors (DFs), and DFs derived from emissions data collected by Baytech during the project, could potentially be used to streamline future OBDII compliance demonstrations.

### Technology Description

Baytech's Sequential MPFI system for CNG consists of an injector block assembly and gas distribution system from each injector to the respective cylinder, injector driver module, coalescing filter, pressure regulator, and electric shut-off valve. Baytech's CNG engine calibration software is implemented in the OEM Powertrain Control Module (PCM), which controls the A/F to stoichiometric (as modified to account for special operating conditions) using oxygen sensors and closed loop control.



A picture of the CNG injector block installed on the test vehicle engine (full size GM 6.0L van) is shown here. Limited space above the van's engine requires using a "split" injector block, with four injectors on each side of the engine.

Baytech's CNG systems fully utilize the OBDII system, which is designed to monitor and detect problems with the vehicle emissions system, although some of the monitors were calibrated on gasoline prior to conducting this project.

### Status

Baytech successfully completed the project in April 2007. A final report is on file with complete technical details of the project.

## **Results**

Baytech received OBDII approval from CARB for a set of CNG light duty vehicles for 2006 and 2007 model years on August 31, 2006, including the full-size van and van cutaway models which were certified to California super ultra low emission vehicle (SULEV) emission standards.

Baytech also conducted an analysis comparing the emissions test results under malfunction conditions using 120K mile-aged components and 4K mile-aged components, with the objective of showing how streamlined methods could potentially be used to demonstrate OBDII compliance for future model years. The potential streamlined methods use worst-case Baytech-derived DFs, based on 4K and 120K mile-aged component testing, to predict the end of life emissions when testing emission malfunctions with 4,000 mile-aged components.

The streamlined approach developed by Baytech was presented to CARB and, if accepted, will benefit other small volume manufacturers. This will be an ongoing process that will continue beyond this project.

## **Benefits**

This project demonstrated to CARB that properly engineered NGVs can be compliant with OBDII requirements. The light duty NGVs that Baytech is able to certify with CARB based on the results of this project provide NGVs that vehicle fleets can purchase to comply with SCAQMD fleet rules for alternative fuels use.

## **Project Costs**

This project was conducted under a fixed price contract with SCAQMD. Total SCAQMD funding was \$319,615; total project co-funding was \$425,282. The project was successfully completed within the fixed price budget.

## **Commercialization and Applications**

Baytech's receipt of CARB OBDII compliance approval, based on data and results generated in this project, enabled Baytech to emissions certify a number of light duty CNG vehicles/engine families in October and November 2006. These are commercialized by Baytech, including the GM full-sized van and pickup truck.

## Conduct Organic Compound Analyses of Particulate Matter Samples Collected Under MATES III

**Contractor**

Desert Research Institute

**Cosponsors**

N/A

**Project Officer**

Aaron Katzenstein

**Background**

The objective of the Multiple Air Toxics Exposure Study (MATES) III is to characterize the ambient air toxic concentrations and potential exposures in the South Coast Air Basin (SoCAB). In addition to ambient measurements, the project will develop an updated toxics emission inventory and conduct air dispersion modeling to estimate ambient levels and potential health risks of air toxics. The results of MATES III will determine the spatial concentration pattern of important hazardous air pollutants in the Basin, assess the effectiveness of current air toxic control measures, provide trend data of air toxic levels, and be used to update and develop appropriate control strategies for reducing exposures to toxics associated with significant public health risk.

Measurements were conducted on volatile organic compounds (VOC), organic and elemental carbon (OC/EC), total carbon (TC), as well as particulate matter, including PM<sub>2.5</sub> mass and metals. The MATES III Technical Advisory Group recommended that a supplemental analysis of organic compounds be conducted on the MATES III PM<sub>2.5</sub> filter samples to provide additional data that may be used to characterize certain sources contributing to ambient particulate matter. The main sources include diesel and gasoline vehicle exhaust, wood smoke, meat charbroiling, road dust, and fuel oil combustion.

**Project Objective**

The specific objective of this work was to analyze quartz filter samples collected during the MATES

III for selected organic compounds listed in Appendix A by gas chromatography/mass spectrometry (GC/MS) technique.

**Technology Description**

To obtain sufficient material needed for organic analyses, PM<sub>2.5</sub> filter samples collected at each of the monitoring sites were composited on a monthly basis and shipped to Desert Research Institute (DRI) in clean jars priority overnight in an ice chest with blue ice. Upon receipt by the laboratory, the samples were logged into the Laboratory Information Management System (LIMS), and field data were recorded (sampling location, date, start and stop time, elapse timer, and flow rate). If the time span between sample login and extraction was greater than 24 hours, the samples were kept cold at 0-4°C in a freezer.

For each composite sample contained in one glass jar, the quartz filters were extracted and analyzed together. Prior to extraction, a set of deuterated internal standards were added to each sample. The amount of internal standards added should correspond to the expected range of concentrations found in real samples and the final volume of extracts during analysis. Filters were extracted with ~170 mL dichloromethane (DCM) using the Dionex ASE (accelerated solvent extractor) for 15 min/cell at 1,500 psi and 80°C followed by ~170 mL acetone extraction under the same conditions. Extracts were concentrated to ~1 mL by rotary evaporation at 35 °C under gentle vacuum, and filtered through a 0.2 µm PTFE disposable filter (Whatman Pura disc™ 25TF), rinsing the flask three times with 1 mL dichloromethane and acetone (50/50 by volume) each time. Filtrate was collected in a 4 mL amber glass vial for a total volume of ~4 mL.

Approximately 200 µl of acetonitrile was added at this time and the extract was split into two fractions. Each fraction was then concentrated under a gentle stream of ultra-high purity (UHP) nitrogen with hydrocarbon and water traps to 100 µL. The final extract volume is adjusted to 100 µL with acetonitrile.



One fraction was analyzed by the GC/MS method for polycyclic aromatic hydrocarbon (PAH), hopanes/steranes, alkanes, and cycloalkanes, as described below. If necessary (in case of very dirty samples), the extracts were precleaned by the solid-phase extraction technique, using Superclean LC-SI SPE cartridges (Supelco) with sequential elution with hexane, and hexane/benzene (1:1). The hexane fraction contains the non-polar aliphatic hydrocarbons (alkanes), and hopanes and steranes, and the hexane/benzene fraction contains the PAH. These two fractions were combined and concentrated to ~100  $\mu$ L and analyzed by GC/MS technique. The second fraction was derivatized using a mixture of bis(trimethylsilyl) trifluoroacetamide and pyridine to convert the polar compounds into their trimethylsilyl derivatives for analysis of organic acids and diacids, cholesterol, methoxyphenols, and levoglucosan. The extract was reduced to a volume of 50  $\mu$ L using a Pierce Reacti-Therm under a gentle stream of ultra-high purity (UHP) nitrogen with a water trap (Chrompack CP-Gas-Clean moisture filter 17971). Then, 50  $\mu$ L of silylation grade pyridine and 150  $\mu$ L of bis(trimethylsilyl)trifluoroacetamide was added slowly to each vial and immediately capped. The sample was then placed into thermal plates (custom made) containing individual vial wells with the temperature maintained at 70°C for 3 hours. The samples were then analyzed by GC/MS within 18 hours.

The extracts were analyzed by gas chromatography/mass spectrometry (GC/MS) using a Varian CP-3800 GC equipped with a CP8400 autosampler and interfaced to a Varian Saturn 2000 Ion Trap (Batch 1 of samples) or Varian 4000 Ion Trap (all remaining Batches) operating in electron impact (EI) ionization mode. Injections (1  $\mu$ L) were made in the splitless mode onto a 30m long 5% phenylmethylsilicone fused-silica capillary column (DB-5ms, J&W Scientific or equivalent). Quantification of the individual compounds was obtained by selective ion storage (SIS) technique, monitoring the molecular and characteristic ions of each compound of interest and the corresponding deuterated internal standard ions. Since hopanes and steranes are usually present in very low concentrations in ambient PM<sub>2.5</sub> samples, a new Varian 1200 triple quadrupole gas chromatograph – mass spectrometer (GC/MS/MS) system was used for these compounds quantification. The superior selectivity and sensitivity of this instrument (in EI/MS SIM mode it reaches 50 fg/  $\mu$ L with 10:1 S/N) allows for accurate analysis of compounds present in very low concentrations.

Calibration curves for the GC/MS quantification were made for the most abundant and characteristic ion peaks of the compounds of interest using the deuterated species most closely matched in volatility and retention characteristics as internal standards. For PAH, National Institute of Standards and Technology (NIST) Standard Reference Material (SRM) 1647 (certified PAH) with the addition of deuterated internal standards and of those compounds not present in the SRM was used to make calibration solutions. For hopanes/steranes, the calibration mixture obtained from NIST and prepared by Chiron AS, Norway, was used. For alkanes and cycloalkanes, the calibration solutions are made from the authentic standards purchased from Aldrich, Accustandard, and Chiron AS. For polar compounds, a separate calibration mixture is prepared using the authentic compounds purchased from various sources (i.e., Aldrich Inc., Accustandard, Chiron AS, and others) and derivatized the same way as described above, just before the analysis. A six- to eight-level calibration is performed for each compound of interest, and the calibration check (using median calibration standards) is run every 10 samples to check for accuracy of analyses. If the relative accuracy of measurement (defined as a percent difference from the standard value) is less than 20%, the instrument is recalibrated. Field blanks and media blanks were analyzed by the same method as actual samples. Approximately 10% of the extracts were run as duplicate analysis, to determine the replicate precision. Field blanks were extracted and analyzed using the same methods.

### **Status**

The analysis of all samples has been completed and the data delivered in electronic form to the program manager. Four batches of data were delivered on 10/13/2005, 12/30/2005, 5/4/2006 and 11/28/2006.

### **Results**

The samples were analyzed for 13 PAH, 24 hopanes and steranes, 17 alkanes/cycloalkanes and 21 polar organic compounds. All data, after level 2 validation, were delivered in electronic form and are available upon request.

### **Benefits**

N/A

### **Project Costs**

The total project cost was \$399,990 over two years.



## **Appendix D**

### **List of Acronyms**



## LIST OF ACRONYMS

AFRC—air/fuel ratio control	MECA—Manufacturers of Emission Controls Association
AQMD—Air Quality Management District	MPFI—Multi-port Fuel Injection
AQMP—Air Quality Management Plan	MSRC—Mobile Source Air Pollution Reduction Review Committee
ARB—Air Resources Board	MTA—Metropolitan Transportation Authority
BACT—Best Available Control Technology	NAFA—National Association of Fleet Administrators
CAAP—Clean Air Action Plan	NGV—natural gas vehicle
CAFR—Comprehensive Annual Financial Report	NMHC—non-methane hydrocarbon
CARB—California Air Resources Board	NO <sub>x</sub> —oxides of nitrogen
CCF—California Clean Fuels	NREL—National Renewables Energy Lab
CEC—California Energy Commission	OBDII—On-Board Diagnostic
CEMS—continuous emission monitoring system	OCTA—Orange County Transit Authority
CNG—compressed natural gas	OEM—original equipment manufacturer
CO <sub>2</sub> —carbon dioxide	PAH—polyaromatic hydrocarbons
CO—carbon monoxide	PbA—lead acid
CY—calendar year	PCM—powertrain control module
DCM—dichloromethane	PHEV—plug-in hybrid vehicle
DDC—Detroit Diesel Corporation	PM—particulate matter
DGE—diesel gallon equivalents	PM <sub>2.5</sub> —particulate matter ≤ 2.5 microns
DF—deterioration factor	PM <sub>10</sub> —particulate matter ≤ 10 microns
DMV—Department of Motor Vehicles	RDD&D—research, development, demonstration, and deployment
DOC—diesel oxidation catalysts	RTA—Riverside Transit Agency
DOE—Department of Energy	SCAB—South Coast Air Basin
DOT—Department of Transportation	SCAQMD—South Coast Air Quality Management District
DPF—diesel particulate filters	SCE—Southern California Edison
DRI—Desert Research Institute	SCR—selective catalytic reduction
ECM—emission control monitoring	SoCAB—South Coast Air Basin
EPRI—Electric Power Research Institute	SULEV—super ultra-low emission vehicle
ESD—emergency shut down	TC—total carbon
EV—electric vehicle	THC—total hydrocarbons
FCV—fuel cell vehicle	TO—task order
FTP—federal test procedures	U.S.EPA—United States Environmental Protection Agency
GC/MS—gas chromatography/mass spectrometry	ULEV—ultra low emission vehicle
GGE—gasoline gallon equivalents	VOC—volatile organic compounds
GHG—Greenhouse Gas	WVU—West Virginia University
GTL—gas to liquid	ZEV—zero emission vehicle
H&SC—California Health and Safety Code	
HCNG—hydrogen-compressed natural gas (blend)	
HEV—Hybrid electric vehicle	
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	
MATES—Multiple Air Toxics Exposure Study	