TECHNOLOGY ADVANCEMENT OFFICE
CLEAN FUELS PROGRAM
2006 ANNUAL REPORT AND
2007 PLAN UPDATE

South Coast Air Quality Management District
March 2007

South Coast Air Quality Management District

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*Technology Committee Members **Technology Committee Chairman

South Coast Air Quality Management District
Technology Advancement Office

Chung S. Liu, D.Env., Deputy Executive Officer, Science & Technology Advancement
Henry Hogo, Assistant Deputy Executive Officer, Science & Technology Advancement

Gary Dixon, Special Project Manager
Larry Kolczak, Community Relations Manager
Fred Minassian, Technology Implementation Manager
Matt Miyasato, Ph.D., Technology Demonstrations Manager
Zorik Pirveysian, Environmental Technologies Assessment Manager
Dean Saito, Mobile Source Strategies Manager
Paul Wuebben, Clean Fuels Officer

Naveen Berry, Program Supervisor
Michael Bogdanoff, Program Supervisor
David Coel, Program Supervisor
Connie Day, Program Supervisor
Ranji George, Program Supervisor
Marty Kay, Program Supervisor
Dipankar Sarkar, Program Supervisor
Larry Watkins, Program Supervisor

Al Baez, Senior Air Quality Engineer
Howard Lange, Ph.D., Air Quality Engineer II

Phil Barroca, P.E., Air Quality Specialist
Suresh Chaurushiya, Air Quality Specialist
Mark Coleman, Air Quality Specialist
Larry Irwin, Air Quality Specialist
Von Loveland, Air Quality Specialist
Lisa Mirisola, Air Quality Specialist
Frank Motavessal, Air Quality Specialist
Adewale Oshinuga, Air Quality Specialist
Randall Pasek, Ph.D., Air Quality Specialist
Shashi Singeetham, Air Quality Specialist
Vicki White, Air Quality Specialist
Vasken Yardemian, Air Quality Specialist

Geri Bowen, Staff Specialist
Phil Yenovkian, Staff Specialist

Dory Kilgour, Senior Administrative Secretary
Drue Ramirez, Senior Administrative Secretary
Penny Shaw Cedillo, Secretary
Majorie Eaton, Secretary
Donna Vernon, Secretary
Lani Montojo, Staff Assistant
Ana Troccoli, Contracts Assistant
Linda Turner, Contracts Assistant
Michelle White, Contracts Assistant
Flor Tumambing, Senior Office Assistant

Other Staff Contributors
Jean Ospital, Ph.D., Health Effects Officer, Planning, Rule Development & Area Sources
Joe Cassmassi, Planning & Rules Manager, AQMP/Special Projects

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EXECUTIVE SUMMARY

2006 Annual Report

The South Coast Air Quality Management District (SCAQMD) executed 65 new projects, studies or amended contracts with expenditures during Calendar Year (CY) 2006 to sponsor research, development, demonstration and deployment (RDD&D) and commercialization of alternative fuel and clean fuel technologies in Southern California. Table 2 (page 19) and Table 5 (page 58) list projects which are further described in this report. The SCAQMD contributed nearly $9 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 $26 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 2006, the AQMD 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 AQMD 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 2006 included expansion of the hydrogen and natural gas alternative fueling infrastructure, development of heavy-duty natural gas engines, and the further conversion of plug-in hybrid electric vehicles. The AQMD also executed two stationary projects to advance low-emission burners for boilers and retrofit applications.

Fourteen research, development, demonstration and deployment projects or studies, 21 technology assessment or outreach projects, and 7 incentive projects were completed in 2006, as listed in Table 4 (page 47). Summaries for each technical project completed in 2006 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, 2007, after approval by the SCAQMD Governing Board.

2007 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 this 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_x), 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 NOx and PM2.5 reductions will be necessary to meet the federal PM2.5 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.

CLEAN FUELS PROGRAM

Introduction

The Basin, which is comprised of the Los Angeles, Orange, San Bernardino, and Riverside counties, has some of 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:

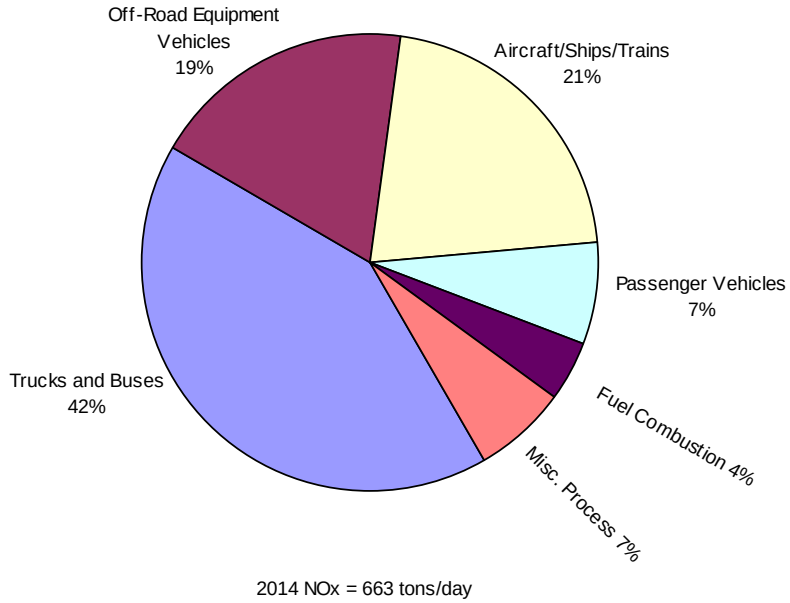
- A description of the core technologies that the SCAQMD considers critical to ensure attainment and maintenance of ambient air quality standards and a description of the efforts made to overcome barriers to commercialization of those technologies;
- An analysis of the impact of the SCAQMD's Clean Fuels 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 Calendar Year (CY) 2006. 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.

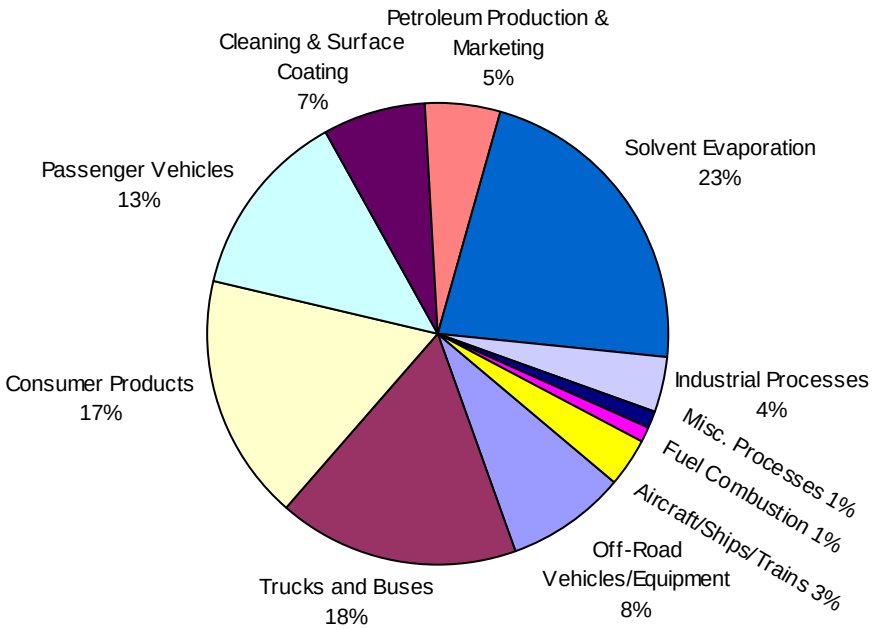
During the period between January 1 and December 31, 2006, the SCAQMD executed 65 projects or studies and amended contracts that support clean fuels and advanced low-emission technologies. The SCAQMD contribution for these projects was nearly $9 million, with total project costs of nearly $26 million. 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 Draft Air Quality Management Plan (AQMP). The baseline 2014 emissions inventory is shown in Figure 1. Based on the 2007 Draft AQMP, significant reductions are necessary to demonstrate attainment with the federal standards.



2014 NOx = 663 tons/day



2014 VOC = 644 tons/day

Figure 1: Major Source Contributions (2014)

To fulfill long-term emission reduction measures, the 2007 Draft 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_x and VOC.

Recent health studies also indicate a greater need to reduce NO_x 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), was initiated in Spring 2004 to evaluate air toxic exposure trends, expand the list of known air toxics, and assess local impacts from industrial, commercial and mobile sources. MATES-III was continued through 2006 and is expected to conclude in 2007.

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) as well as limit the amount of greenhouse gases emitted from automobiles starting in 2009 (AB 1493). The goals of the federal and state programs will be achieved, in part, through alternative fuels (petroleum displacement) and increased vehicle hybridization (improved efficiency).

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 2006 the funds available through each of these mechanisms were as follows:

- Mobile sources (DMV revenues) $ 12,294,588
- Stationary sources (emission fee surcharge) $ 364,549

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 2006.

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.

A second advisory group was formed as required by SB 98 (Alarcon). Under H&SC Section 40448.5.1(c), this advisory group must be comprised of 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_x 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.

In 2006, the SCAQMD continued to aggressively add and upgrade natural gas fueling facilities to support the need for compressed natural gas (CNG) and liquefied natural gas (LNG) fuel by fleet operators subject to clean-fuel fleet requirements. The SCAQMD also continued to support early commercial deployment of alternative fuel light-duty vehicles by offering funding incentives to taxicab operators at airports for the purchase of Rule 1194 compliant alternative-fuel taxicabs.

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, increased public attention on global warming, and the upcoming (Spring 2007) reconsideration of the Zero Emission Vehicle (ZEV) regulation for California. The federal government has announced commitments to pursue a plug-in hybrid electric vehicle (PHEV) capable of 40 miles all-electric range, and the state of California has dedicated funding through AB 1811 to support alternative fuel projects, including hybrids and PHEVs. 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., ICE and fuel cells).

Engine Technologies

Medium- and heavy-duty vehicles contribute over 60% of the Basin's NO_x and almost 30% of the VOC emissions. More importantly, heavy-duty diesel engines contribute over 40% of the mobile source particulate emissions, which have known toxic effects. Significant emission reductions will be required from mobile sources, especially from the heavy-duty sector, to attain federal clean air standards.

The use of alternative fuels in heavy-duty vehicles can provide significant reductions in NO_x and particulate emissions. The current NO_x emissions standard for heavy-duty engines is 1.2 g/bhp-hr (combined NO_x and VOC emissions), and there is currently only one heavy-duty natural gas engine with demonstrated NOx 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 CNG and 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 state's ZEV regulation, which requires the automakers to demonstrate 250 fuel cell vehicles by 2008, will be reviewed this spring to determine if the increased numbers due in 2011 (2,500 vehicles) and 2014 (25,000) are possible.

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. Ford recently demonstrated this concept, a plug-in fuel cell vehicle, at the Detroit Auto Show in December 2006. 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 are 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.

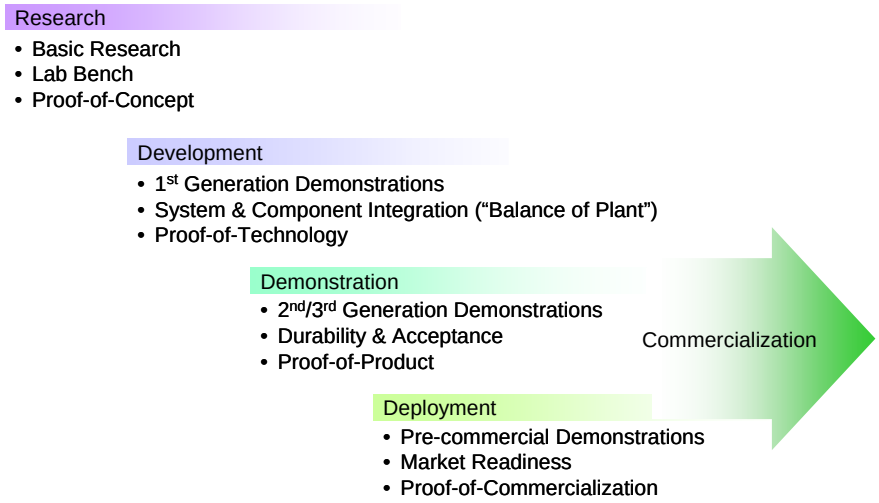


Figure 2: Clean Fuels Program Project Types

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
  - Cummins: C8.3L (CNG, LNG), B5.9L (CNG), L10 (CNG), ISX 15L (LNG)
  - Detroit Diesel: Series 60G (CNG/LNG), Series 50G (CNG/LNG)
  - John Deere: 6068 (CNG), 6081 (CNG)
  - Mack: E7-400G (LNG)

  - Clean Air Partners/Power Systems (Catepillar): 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
  - 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
  - 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
  - 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 formally 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 2006 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 2006

Research Funding Organizations	Major Manufacturers/Providers
California Air Resources Board	Clean Energy Fuels Corporation
California Energy Commission	Cummins Westport
National Renewable Energy Laboratory	Gas Technology Institute
San Diego Air Pollution Control District	John Deere Power Systems
U.S. Department of Energy	ISE Corporation
	R.F. Dickson
	San Diego Metro
	SunLine Transit Agency

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 2006. 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 electric vehicle technologies.

Heavy-Duty Engines

Heavy-duty vehicles contribute the majority of NOx 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. Three projects contracted during CY 2006 were to develop natural gas engines capable of meeting the stringent 2010 federal emissions standards. Two awards were to major engine manufacturers, John Deere and Cummins Westport, and one was to a small volume manufacturer, Baytech Corporation, to convert a GM engine while developing the capability to satisfy the state On-Board Diagnostic (OBD) II requirements. These three projects represent a range of engine sizes, vehicle platforms, and applications. The John Deere 9L engine has applications in street sweepers, delivery trucks, and Type C school buses; the Cummins Westport 8.9L Gas Plus has applications in transit buses and trash trucks, and the Baytech engine can be used in municipal fleet applications such as full-size and cut-away vans. For all of these applications, however, there is a common strategy to apply combustion modifications, increased exhaust gas recirculation, and catalyst technology. A fourth project contracted in CY 2006 was to evaluate a hydrogen-natural gas (HCNG) mixture in ICEs with NOx aftertreatment. City Engines Inc. will modify an existing 11.0L Doosan engine to operate on a 30% mixture of hydrogen blended into natural gas, and in cooperation with the Los Angeles County MTA demonstrate two CNG transit buses along side the two on the HCNG mixture for six months. City Engines plans to commercialize this engine in the near future.

Plug-in Hybrid Vehicles

The AQMD has actively sponsored the development of PHEVs for light-duty and medium-duty platforms. For the light-duty application, the SCAQMD has supported EnergyCS to convert up to four Toyota Prius vehicles to PHEVs utilizing Valence lithium-ion batteries. Working with EnergyCS

in the early demonstration testing of the first prototype vehicle has identified a variety of areas for potential improvement, including battery pack balancing and optimization, charger durability, engine-on strategy and cold-start emissions reductions, consideration of different size battery packs, and simplification of the user display screen.

Figure 3: EnergyCS Vehicle & Hybrid Sprinter with Plug-In Technology

For the medium-duty application, the SCAQMD has partnered with EPRI, DaimlerChrylser, and SCE to develop and test two different battery technologies for a PHEV delivery van. Lithium-ion and nikel metal hydride battery packs were installed and are undergoing performance and durability testing. Initial results have led DaimlerChrysler to select the lithium-ion battery technology for further demonstrations in a global program of thirty vehicles.

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 describes two projects which demonstrate the impact of the SCAQMD program on technology deployment and commercialization during the CY 2006 reporting period.

Heavy, Heavy-Duty Natural Gas Engine for Class 8 Trucks

There are no natural gas engines available in North America with ratings above approximately 320hp. The market for Class 8 tractors typically requires engines with ratings above 400hp. Development of viable natural gas fueled engines meeting the performance requirements for Class 8 tractors would extend the availability of alternative fueled, clean engines into applications with typically the highest emissions of air contaminants and the highest consumption of petroleum-based fuels.

Figure 4: Westport Innovation HPDI Engine

In partnership with NREL and Westport, the project objective was to advance the readiness of Westport's

high pressure direct injection (HPDI) technology using LNG as a fuel for Class 8 tractor engines. The project targeted development of 400hp and 450hp heavy-duty engine ratings based around a 15 liter Cummins ISX diesel engine platform. As well as technology development, the project scope required demonstration of production ready engines in a commercial fleet; and the development of initial low volume manufacturing capability to facilitate subsequent commercial availability of the technology, with engines certified at or below 1.2g/bhp-hr NOx and 0.1 g/bhp-hr for Particulate Matter (PM).

Figure 5: Demonstration Class 8 Tractor with HPDI Engine

Westport's proprietary HPDI technology facilitates the use of natural gas as an engine fuel while retaining typical diesel engine combustion, power and torque. A unique and patented injector design delivers a small volume, approximately 6% by energy, of diesel as the ignition source, and high pressure natural gas directly to the engine combustion chamber. With the low emissions profile of natural gas, and the high efficiency of a diesel combustion cycle, the technology offers potential for combining high energy efficiency with low emissions. The HPDI system includes the fully integrated electronics, LNG tanks and vehicle installation.

During the 18-month project, certification testing of the HPDI system was completed. The NOx emissions represent an approximate 50% reduction compared to the equivalent model year diesel engine and 80% for PM.

The figure below represents the key performance characteristics of the HPDI system as developed during the project:

Rating 1	400 hp @ 1800 rpm 1,450 lb-ft @ 1200 rpm
Rating 2	450 hp @ 1800 rpm 1,650 lb-ft @ 1200 rpm
EPA Cert	1.2g NOx, 0.02g PM
Emission Control	EGR + Oxicat

Figure 6: HPDI Performance Summary

In March 2006 a CARB Executive Order was issued for the product. Shortly thereafter, three demonstration HPDI systems were delivered to Norcal Waste Systems in San Francisco. The development engineering conducted extended fuel efficiency in a second trial fleet to within 2% of equivalent diesel trucks. Through the advancements made during this project, the HPDI technology has been made commercially available for Class 8 truck applications in introductory volumes with customer deliveries expected for Q2 2007.

Future developments in the technology for prolonged commercial application include development of emissions control solutions to meet the 0.2 g/bhp-hr NOx 2010 EPA emissions standards. Vehicle integration and OEM availability are key aspects of making further market penetration of the technology.

Portable Electrochemical Analysers

In a program of random testing of operating internal combustion engines in the field, AQMD found that rich-burn engines frequently exceed permit NOx and CO emission limits by wide margins. To remedy this problem, AQMD plans to amend Rule 1110.2 to require more monitoring of rich-burn engine emissions. One possible approach is to allow the use of relatively low-cost portable electrochemical cell-based analyzers to monitor emissions on a semi-continuous basis. This approach would be much less costly to the engine owner than a certified continuous emission monitoring system (CEMS), which is the method normally used when close tracking of emission performance is deemed necessary. Although emission data produced by an electrochemical cell-based system are not as accurate as CEMS data, the information produced by such a system would be adequate to enable the engine operator to avoid the large emission exceedances that are presently occurring on many rich-burn engines.

Figure 7: Testo 350X1 Portable Analyzer

This project was initiated to explore the feasibility and costs involved in adapting a portable electrochemical analyzer to serve as a semi-continuous emission monitoring system on a rich-burn engine.

The project was performed by Advanced Engine Technologies Corporation (AETC). To address the project objective, AETC set up two Testo portable electrochemical analyzers to record NO, CO and O2 emissions from a rich-burn engine located at Eastern Municipal Water District's Perris water treatment facility while simultaneously measuring the same emissions using a certified transportable CEMS (T-CEMS).

One analyzer (Testo 1) was installed in a temperature-controlled environment in the T-CEMS trailer. The other (Testo 2) was installed "in the elements" on the roof adjacent to the stack. To define the maximum sampling frequency consistent with acceptable long-term performance of the electrochemical analyzer, the sample rate was optimized during the test program. The team settled on two data sampling scenarios. The Testo 1 analyzer sampled for 15 minutes every hour, and the Testo 2 sampled for 15 minutes every 8 hours. These sampling rates also served to provide insight for long-term maintenance and cost evaluations.

Operating its T-CEMS in parallel with the Testo analyzers AETC compiled a contemporaneous database of emissions data from each device along with engine data. The tests generated approximately 700 hours of usable data over a wide range of emission levels.

The NO portion of both Testo analyzers exhibited excellent agreement with the T-CEMS NO results, and the performance of the roof-mounted Testo was not adversely affected by being exposed to external ambient conditions.

The Testo CO analyzers exhibited significantly different results from the CEMS CO analyzer. In general, the CO data was highly correlated. However, the Testo CO sensor response indicated about half the CEMS CO at low levels (~100 ppm CEMS) but agreed with the CEMs at higher levels (~300 ppm). Investigation of this bias problem showed that the CEMS CO analyzer responds not only to CO but also to nitrous oxide (N2O), which rich-burn engines tend to generate. The Testo CO cell

does not respond to N2O. Consequently it was not possible to make any comparative assessment of the CEMS and Testo CO data.

The CEMS paramagnetic O2 analyzer is not accurate or precise at the low O2 levels at which rich-burn engines operate (0 – 0.5%) but is useful to indicate the presence of air leakage into the gas sampling system.

During the two and one-half month duration of the test, the two Testo analyzers suffered five CO cell failures and two NO cell failure. Some of these failures may have been induced by malfunction and/or misunderstanding of the purge and dilution requirements. However, it appears that even brief uncontrolled emissions excursions in the rich direction bias and even poison the CO cells.

For the Testo analyzer to become a useful semi-continuous monitoring system, Testo will need to upgrade the software or end users will need to provide their own data acquisition, retrieval and reporting systems.

The sample handling and conditioning system worked extremely well, and the robustness and overall "plug and play" nature of the Testo package greatly simplifies maintenance in comparison to a conventional CEMS. The NO cell offered excellent performance and the O2 cell seemed credible. Presumably, the CO cell will offer similar performance once Testo resolves the CO cell failure problem and the CEMS N2O interference issue is resolved. The project showed that, while the Testo analyzer is not a replacement for a CEMS, when properly configured it could potentially serve as a viable semi-continuous emission monitoring system for a rich-burn engine. The CO cell life and software modifications require further evaluation to determine the relative cost-effectiveness.

2006 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, 2006.

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, 2006, sixty-five contracts 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 8. This wide array of technology support represents the AQMD'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 2006 reporting period are shown below with the total project costs:

SCAQMD Clean Fuels Fund Contribution	$ 8,857,833
Total Cost of Clean Fuels Projects	$ 25,780,378

Each year, the Governing Board approves funds to be transferred to the General Fund Budget for Clean Fuels administration. For 2006, the Board transferred $500,000 for workshops, conferences, co-sponsorships and outreach activities as well as postage, supplies, and travel costs for special conferences. Only the funds committed by December 31, 2006, are included within this report. Any portion of the Clean Fuels Funds not spent by the end of Fiscal Year 2006-07 ending June 30, 2007, 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, 2007.

For Clean Fuels executed or amended contracts in 2006, the average SCAQMD contribution was 34 percent of the total cost of the projects, identifying that each dollar from the SCAQMD was leveraged with more than three dollars of outside investment.

During 2006, the SCAQMD executed contracts or amendments with expenditures of nearly $9 million for Clean Fuels projects. The distribution of funds for executed contracts is shown in Figure 8 below.

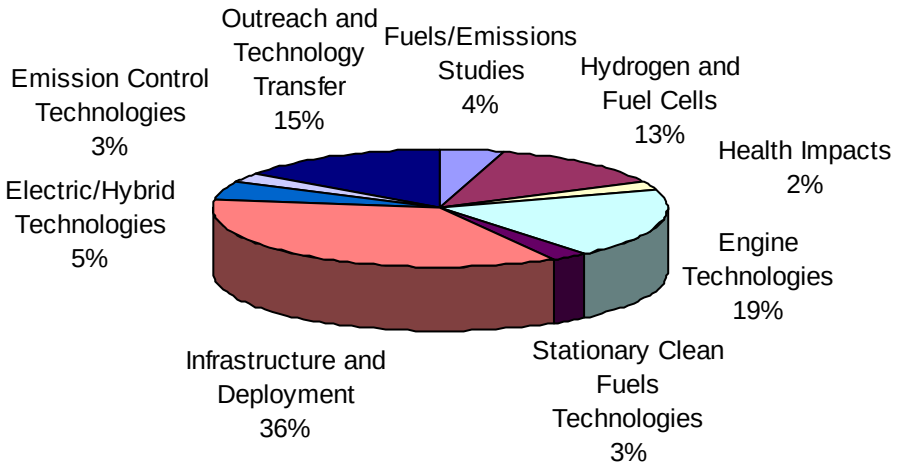


Figure 8: Distribution of Funds for Executed Clean Fuels Projects CY 2006 ($9 million)

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, 2006, 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, 2006

Contract	Contractor	Project Title	Start Term	End Term	AQMD $	Project Total $
Infrastructure and Deployment						
06000	Gas Equipment Systems, Inc.	Purchase & Install New CNG Fueling System at County of LA Dept. of Beaches and Harbors' Malibu Facility	09/05/06	12/31/12	150,000	525,000
06030	Clean Energy	Purchase & Install CNG Fueling 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 Fueling 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 Fueling 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 Fueling 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 Fueling 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 Fueling Systems at City of San Fernando Public Works Dept. Yard	12/15/06	12/31/12	73,200	486,000
07003	Fontana Unified School District	Install CNG Infrastructure and Perform Garage Upgrades	09/05/06	12/31/07	322,000	450,000
07014	Gas Equipment Systems Inc.	Purchase & Install New CNG Fueling 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 Fueling Station	12/28/06	12/31/12	165,000	550,000
Direct	Various	Purchase Natural Gas Vehicles for Taxicab Services	05/05/06	05/05/06	1,000,000	1,547,400
Fuels/Emission Studies						
06157	City of Santa Monica	Develop & Demonstrate Biodiesel Fuel with Selective Catalytic Reduction	06/26/06	08/31/07	140,000	280,000

Table 2: Contracts Initiated or Amended between January 1 and December 31, 2006 (cont'd)

Contract	Contractor	Project Title	Start Term	End Term	AQMD $	Project Total $
Fuels/Emission Studies (cont'd)						
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 Model Years 2004 & 2005 Classes 7-8 Heavy-Duty Diesel and Natural Gas Fueled Trucks	12/13/06	08/15/07	240,000	240,000
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	08/31/07	260,000	552,580
Electric/Hybrid Technologies						
06182	ISE Research Corporation	Develop & Demonstrate a Natural Gas Hybrid-Electric Transit Bus	08/25/06	08/31/08	300,000	1,050,000
05260	EnergyCS	Conversion of Light-Duty Vehicle to Plug-In Hybrid Vehicles	09/09/05	10/03/08	130,000	446,000
Engine Technologies						
05244	Cummins Westport, Inc.	Develop, Demonstrate & Certify Heavy-Duty Natural Gas Engine to Meet 2010 Emission Standards	08/26/05	07/31/07	700,000	700,000
06033	John Deere Power Systems	Develop & Certify a Medium- and Heavy-Duty Natural Gas Engine	03/15/06	04/30/07	695,400	5,820,749
06068	Baytech Corporation	Develop & Demonstrate On-Board Diagnostic Systems for Natural Gas Vehicles	01/20/06	01/30/07	319,615	774,896
Hydrogen Technologies and Infrastructure						
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 Hydrogen Refueling Station in Coachella Valley	10/19/06	03/31/08	640,000	1,200,000
Mobile Fuel Cell Technologies						
04126	American Honda Motor Company	Lease of One Additional Honda Fuel Cell Electric Vehicle	06/22/04	07/23/07	12,990	12,990
Health Impacts Studies						
05172	Desert Research Institute	Organic Compound Analyses of Particulate Matter Samples Collected Under MATES III	08/13/05	01/31/07	200,000	200,000
Stationary Clean Fuels Technology						
06017	Gas Technology Institute	Field Demonstration of Advance Technology Boiler in South Coast District	03/15/06	12/15/07	135,000	612,146

Table 2: Contracts Initiated or Amended between January 1 and December 31, 2006 (cont'd)

Contract	Contractor	Project Title	Start Term	End Term	AQMD $	Project Total $
Stationary Clean Fuels Technology (cont'd)						
07017	Gas Technology Institute	Field Demonstration of 5-PPM FIR Ultra-Low NOx Burner on a Watertube Boiler	10/19/06	07/18/07	90,000	300,000
Outreach and Technology Transfer						
04049	Engine, Fuel & Emissions Engineering Inc.	Technical Assistance for Alt Fuels Engine Technology	11/21/03	12/31/07	60,000	60,000
05008	Bevilacqua-Knight Inc.	Participate in California Fuel Cell Partnership for CY 2006 & Provide Support for Regional Coordinator	07/07/04	07/06/07	133,800	2,213,274
05120	Clean Fuel Connection, Inc.	Technical Assistance for Technology Incentive Programs to Evaluate Proposals for Compliance	04/01/05	03/31/07	40,000	40,000
05171	James Hazelton	Technical Assistance on AB 1222 Advisory Group	04/08/05	03/31/07	25,000	25,000
06109	Burnett & Burnette	Update & Expand School Bus Inventory in Basin	04/13/06	04/12/07	50,000	50,000
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	75,000	75,000
06173	Maria Robles	Administrative Assistance Services Related to Organization of International Conferences on Asthma and Port Emissions Control Technologies	05/12/06	08/31/07	125,000	125,000
06203	Harold Haskew & Associates Inc	Technical Assistance for AQMD Ethanol Forum & Technical Roundtable	06/25/06	06/30/06	5,000	5,000
06217	Electric Power Research Institute	Technical Assistance for AQMD Plug-In Hybrid Electric Vehicle Forum & Roundtable	06/23/06	11/30/06	20,000	20,000
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	09/21/07	2,901	2,901
07059	Dowling Associates, Inc.	Technical Assistance Related to Air Quality Impacts of Regional Goods	12/19/06	11/30/08	58,000	58,000
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

Table 2: Contracts Initiated or Amended between January 1 and December 31, 2006 (cont'd)

Contract	Contractor	Project Title	Start Term	End Term	AQMD $	Project Total $
Outreach and Technology Transfer (cont'd)						
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
07125	Network Public Affairs, LLC	Technical Assistance for Container Movement Forum and Roundtable	12/26/06	07/31/07	11,000	11,000
Direct	Transfer from Clean Fuels	Conduct & Host International Clean Ports Conference in Spring 2007	07/14/06	07/14/06	150,000	150,000
Varies	Various Contractors	Co-Sponsorships of Conferences, Workshops and Events, plus Memberships	Varies	Varies	145,655	941,000

Table 3: Supplemental Grants/Revenue Received between January 1 and December 31, 2006

Revenue Agreement	Revenue Source	Project Title	Contractor	SCAQMD Project	Total
Interagency Agreement	CARB	Develop & Demonstrate a Natural Gas Hybrid-Electric Transit Bus	ISE Research Corporation	Contract #06182	$100,000

Project Summaries

The following represents the summaries of the projects and studies executed or amended with additional dollars in 2006. They are listed in the order found in Table 2, by category and contract number. The summaries provide the project title, contractors and subcontractors, SCAQMD cost-share, co-sponsors and their respective contributions, contract term, and a description of the projects as required by H&SC Section 40448.5.1 (d).

Infrastructure and Fuel Production

06000: Purchase & Install New CNG Fueling System at County of LA Dept. of Beaches & Harbors' Malibu Facility

Contractor:	Gas Equipment Systems, Inc. (GESI)	SCAQMD Cost-share:	$	150,000
		Cosponsor:		
		GESI		375,000
Term:	09/05/06 – 12/31/12	Total Cost:	$	525,000

This project will provide cost-share funding for a publicly accessible CNG station at the County of Los Angeles' Department of Beaches and Harbors' Will Rogers State Beach maintenance yard. It is the County's goal to purchase additional CNG heavy-duty vehicles and fast fill them. The station will have two compressors to ensure that the County will always be able to refuel their vehicles should one compressor go down. The CNG fuel dispensers will be situated to accommodate traffic flow of several different kinds of heavy-duty trucks. A universal card reader system will be incorporated to handle fueling and billing transactions.

06030: Purchase & Install CNG Fueling Station at Foothill Transit's Pomona Facility

Contractor:	Clean Energy	SCAQMD Cost-share:	$	92,506
		Cosponsor:		
		Clean Energy		157,494
Term:	04/13/06 – 12/31/11	Total Cost:	$	250,000

This project will provide cost-share funding for a publicly accessible CNG station in the City of Pomona next to the Foothill Transit facility. The station address is 200 S. East End Avenue, Pomona. The new station would serve as a crucial fueling stop for the growing number of fleets traveling throughout the eastern portion of Los Angeles County as well as the Inland Empire. The existing station at Foothill Transit is not accessible to outside users. The station will benefit various fleets operating in the area including Yellow Cab Co., Inland Express Shuttle, Diversified Paratransit, Pomona Unified School District, and Universal Waste Systems. The station will have three compressors to ensure efficient refueling of vehicles should one compressor go down, with a total capacity of 4,200 SCFM. The CNG fuel dispensers will be situated to accommodate traffic flow of several different kinds of heavy-duty trucks. A universal card reader system will be incorporated to handle fueling and billing transactions.

06031: Upgrade CNG Station at Bellflower Facility

Contractor:	R.F. Dickson Co., Inc.	SCAQMD Cost-share:	$	211,148
		Cosponsor:		
		R.F. Dickson Co., Inc.		492,680
Term:	04/13/06 – 12/31/11	Total Cost:	$	703,828

This project will provide a second compressor, a second fast-fill fuel dispenser and three additional storage vessels at an existing fueling station, providing a significant improvement in the station's ability to service increasing numbers of large fleet vehicles in a timely and convenient manner. The upgrade will enhance reliability by providing redundancy, improve speed of service and ensure the ability of the station to operate in an efficient manner that is not intrusive to neighbors. The added storage will minimize the need to operate the compressor at night, avoiding local area complaints regarding noise.

06042: Upgrade Existing CNG Public Access Station with Dispenser & Card Reader

Contractor:	UCLA Fleet & Transit Services	SCAQMD Cost-share:	$	15,921
		Cosponsor:		
		UCLA Fleet & Transit Services		15,921
Term:	09/05/06 – 12/31/11	Total Cost:	$	31,842

UCLA Fleet & Transit Services owns and operates a public access fast-fill CNG station that was originally built in 1993. The station is equipped with one dual nozzle fuel dispenser and has been managed by the Gas Company using the E.J. Ward fleet card reader system at the site and provided billing services for the station owners. Unfortunately, the Gas Company is planning to discontinue this service. Funding this project will assist UCLA Fleet & Transit Services to upgrade the public access fast-fill CNG station at their location with a new card reader and dispenser.

06043: Purchase & Install CNG Fueling Station at Joint Water Pollution Control Plant in Carson City

Contractor:	County Sanitation Districts of Los Angeles (CSDLA)	SCAQMD Cost-share:	$	250,000
		Cosponsor:		
		CSDLA		600,000
Term:	03/10/06 – 12/31/11	Total Cost:	$	850,000

The location of the proposed fueling station is ideal for fueling of the Sanitation Districts' fleets and for other fleets in the area. The City of Carson with a fleet of CNG vehicles and the local yellow cab company expressed interest in using the proposed station for their fueling. The City of Carson currently runs nine CNG vehicles and has plans to convert more when a fueling station is more accessible. The estimated usage between the cab company and the City of Carson is about 400,000 gallons equivalent per year once their conversion program is implemented. Currently, the Sanitation Districts has 3 passenger vehicles at the site and plans to replace the entire fleet of about 120 vehicles to use CNG over the next five years. Therefore, by the end of five years, the total usage at this station including estimated public usage is about 450,000 gallons per year, which is conservative because other local fleets may use the station but have not yet committed.

06074: Purchase & Install New Public Access CNG Fueling Station at City Yard

Contractor: City of Sierra Madre — SCAQMD Cost-share: $ 73,776

Cosponsor:

Congressional Earmark 295,104

Term: 03/16/06 – 12/31/11 — Total Cost: $ 368,880

The City of Sierra Madre is requesting SCAQMD cost-share funds in the amount of $73,776 to construct a timed-fill CNG fueling station at its City Yard. The proposed fueling station would be a limited public access facility deriving its natural gas source from a Southern California Gas Company (SoCalGas) meter. Total project cost is estimated at $368,880 with $295,104 allocated from a FY 2003 Congressional Earmark. Proposed fueling throughput from the station is estimated at 80-100 SCFM with commitments from the Cities of Arcadia & Monrovia, School Districts of Arcadia & Pasadena, SoCalGas, and Foothill Transit to utilize the proposed facility for fueling their fleet vehicles.

06082: Purchase & Install New 24-Hour Public Access CNG Fueling Station at SoCalGas's Canoga Park Facility

Contractor: Clean Energy — SCAQMD Cost-share: $ 250,000

Cosponsor:

Clean Energy 592,050

Term: 03/13/06 – 12/31/11 — Total Cost: $ 842,050

This project will provide cost-share funding for a publicly accessible CNG station at the SoCalGas's Canoga Park Base. The new station would serve as a crucial fueling stop for the growing number of fleets traveling throughout the Los Angeles Basin, specifically in the west San Fernando Valley. The station will benefit taxi fleets operating in the area as well as commercial fleets such as Time Warner Cable. The station will have two compressors to ensure that the County will always be able to refuel their vehicles should one compressor go down, with a total capacity of 700 SCFM. The CNG fuel dispensers will be situated to accommodate traffic flow of several different kinds of heavy-duty trucks. A universal card reader system will be incorporated to handle fueling and billing transactions.

06084: Upgrade Existing LNG Facility to L/CNG at Riverside County Waste Management Dept's Aqua Mansa Facility in Riverside

Contractor: Clean Energy — SCAQMD Cost-share: $ 120,000

Cosponsor:

Clean Energy 280,000

Term: 04/13/06 – 12/31/11 — Total Cost: $ 400,000

This project will provide cost-share funding for a new publicly accessible CNG station at an existing LNG fueling station at 1830 Aqua Mansa Road in Riverside. The station will be constructed with state of the art equipment including a dispensing system capable of accepting Visa and MasterCard transactions plus a video screen to train new CNG users. LNG is pumped to high pressure using a cryogenic pump then passed through an ambient vaporizer where it becomes a high pressure gas. From there it is stored in storage vessels. The CNG station will benefit both light- and heavy-duty fleets within the Inland Empire. The CNG fuel dispensers will be situated to accommodate traffic

flow of several different kinds of heavy-duty trucks. A universal card reader system will be incorporated to handle fueling and billing transactions.

06091: Purchase & Install New Public Access CNG Fueling Station at City Yard

Contractor:	City of Whittier	SCAQMD Cost-share:	$	150,000
	Cosponsor:			
		GESI		300,000
Term:	03/18/06 – 12/31/11	Total Cost:	$	450,000

The City of Whittier has just recently embarked on an NGV program that eventually entails the replacement of their entire fleet, including 50 heavy-duty vehicles to operate on CNG. The City is partnering with Gas Equipment Systems, Inc. (GESI), a turnkey supplier of CNG stations, and together will build a CNG station at their corporation yard located at 12016 Hadley St. in Whittier, California. It is their goal to purchase four additional CNG heavy-duty trucks and fill them overnight on the time-fill posts. The station, which will be open to the public as well as other fleets, will have a fast-fill dispenser with two hoses capable of refueling vehicles up to 3600 psi within 5 to 10 minutes, depending upon the type of vehicle being refueled. The CNG station itself will have two compressors to ensure it will always be able refuel city vehicles should one compressor go down.

06139: Purchase & Install New Public Access CNG Fueling Station at Maintenance Yard

Contractor:	Lake Elsinore Unified School District	SCAQMD Cost-share:	$	128,000
	Cosponsor:			
		Lake Elsinore USD		239,000
Term:	06/29/06 – 12/31/11	Total Cost:	$	367,000

This project will provide cost-share funding for a publicly accessible CNG station at the Lake Elsinore Unified School District (LEUSD) bus yard located at 21641 Bundy Canyon Road, Wildomar. LEUSD will install two compressors producing 116 SCFM. The station will primarily be a time-fill, but will have the capability to fast-fill buses and other third party vehicles on a limited basis. Although the station will not be equipped with a fast-fill dispenser, one of the time-fill hoses will be set up for quasi fast-fill to dispense the full compressor output, if needed. LEUSD anticipates having 7 buses initially and up to 25 natural gas powered buses at the end of the third year. LEUSD anticipates using approximately 140 diesel gallon equivalents per day by the end of the third year.

06237: Upgrade Existing Public Access Station with New Dispenser and Card Reader

Contractor:	Whittier Union High School District	SCAQMD Cost-share:	$	15,921
	Cosponsor:			
		MSRC/AB2766 Discretionary Fund		15,921
Term:	10/02/06 – 12/31/12	Total Cost:	$	31,832

Whittier Union High School District owns and operates a public access fast-fill CNG station that was originally built in 1997. The station is equipped with one dual nozzle fuel dispenser and has been managed by SoCalGas using the E.J. Ward fleet card reader system at the site and provided billing

services for the station owners. Unfortunately, SoCalGas is planning to discontinue this service. Funding this project will assist Whittier Union High School District in upgrading the public access fast-fill CNG station at their location with a new card reader and dispenser.

06238: Purchase & Install New CNG Fueling Systems at City of San Fernando Public Works Dept. Yard

Contractor: Gas Equipment Systems, Inc. (GESI)		SCAQMD Cost-share:	$ 73,200
	Cosponsors:		
		AES Settlement Fund	46,800
		City of San Fernando	219,600
		MSRC/AB2766 Discretionary Fund	146,400
Term: 12/15/06 – 12/31/12		Total Cost:	$ 486,000

This project will provide cost-share funding for a publicly accessible CNG station at the City of San Fernando, which has chosen GESI to build the station. The City has embarked on an NGV program that will eventually entail the replacement of the entire fleet. The proposed CNG station is one-half mile off the 5, 210 and 118 freeways and is within three blocks of the Los Angeles County Courthouse and police facilities. The station will have two compressors to ensure that the County will always be able to refuel their vehicles should one compressor go down. The CNG fuel dispensers will be situated to accommodate traffic flow of several different kinds of heavy-duty trucks. A universal card reader system will be incorporated to handle fueling and billing transactions.

07003: Install CNG Infrastructure and Perform Garage Upgrades

Contractor: Fontana Unified School District		SCAQMD Cost-share:	$ 322,000
	Cosponsor:		
		Lower-Emission School Bus Replacement Program/Fund 33	128,000
Term: 09/05/06 – 12/31/07		Total Cost:	$ 450,000

Fontana Unified School District has the largest fleet of the oldest pre-1977 school buses in the Basin. Replacement of these buses with new CNG school buses will require the installation of a relatively large-sized fueling infrastructure with its associated garage upgrades. As part of the FY 2006-07 Lower-Emission Pre-1977 School Bus Replacement Program, Fontana USD is entitled to $16,000 per bus for infrastructure, but this only amounts to $128,000 since they have eight pre-1977 buses. Therefore, the AQMD through its Clean Fuels Fund awarded the additional amount of $322,000 to fully pay the costs of installing new CNG infrastructure and garage upgrades.

07014: Purchase & Install New CNG Fueling System at County of Los Angeles, Dept. of Beaches & Harbors Facility in Zuma Beach

Contractor: Gas Equipment Systems, Inc. (GESI)		SCAQMD Cost-share:	$ 150,000
	Cosponsor:		
		GESI	375,000
Term: 12/15/06 – 12/31/12		Total Cost:	$ 525,000

This project will provide cost-share funding for a publicly accessible CNG station at the County of Los Angeles' Department of Beaches and Harbors' Zuma State Beach maintenance yard. It is the County's goal to purchase additional CNG heavy-duty vehicles and fast fill them. The station will have two compressors to ensure that the County will always be able to refuel their vehicles should one compressor go down. The CNG fuel dispensers will be situated to accommodate traffic flow of several different kinds of heavy-duty trucks. A universal card reader system will be incorporated to handle fueling and billing transactions.

07051: Purchase & Install New Public Access CNG Fueling Station

Contractor: City of Pasadena	SCAQMD Cost-share:	$	165,000
	Cosponsor:		
	City of Pasadena		385,000
Term: 12/28/06 – 12/31/12	Total Cost:	$	550,000

This project will provide cost-share funding for a publicly accessible CNG station at the Pasadena City Yard on 323 West Mountain Avenue, Pasadena. The City of Pasadena has a 700-vehicle fleet but only has one CNG street sweeper. The City is planning on purchasing five more heavy duty vehicles in the next three months and will convert an additional eight refuse trucks from diesel to CNG by the end of 2005. Although the station will not be equipped with a fast-fill dispenser, one of the time-fill hoses will be set up for quasi fast fill to dispense the full compressor output, if needed. The station will have a new 150 SCFM compressor which will be hydrogen compatible. The City anticipates using 800 DEG/day by the end of the third full year of operation.

Direct: Purchase Natural Gas Vehicles for Taxicab Services

Contractor: Various Taxicab Owners	SCAQMD Cost-share:	$	1,000,000
	Cosponsor:		
	AQIP		547,400
Term: n/a	Total Cost:	$	1,547,400

The Board approved $547,400 (up to $23,800 per vehicle) from the Air Quality Investment Program (AQIP) to assist in the buy-down of a minimum of 23 natural gas-fueled vehicles to reduce emissions associated with taxicab services provided at commercial airports. To further incentivize the purchase of cleaner natural gas vehicles for taxicab services at commercial airports, the Board also approved an allocation of $1,000,000 from the Clean Fuels Fund to assist in the buy-down of an additional 42 natural gas-fueled vehicles for taxicab services at commercial airports. The buy-down program will be implemented by staff in the same manner as previous natural gas-fueled taxicab buy-down programs. A maximum of $23,800 of co-funding would be available per vehicle and would be reduced by the federal tax credit if it is available to the purchaser. The emission reductions associated with the buy-down program will be accounted for as part of the Rule 2202 emission reduction target for those taxicabs that are funded by this program.

Fuels/Emission Studies

06157: Develop & Demonstrate Biodiesel Fuel with Selective Catalytic Reduction

Contractor: City of Santa Monica	SCAQMD Cost-share:	$	140,000
	Cosponsors:		
	City of Santa Monica		30,000
	LA BioFuel		30,000
	National Renewable Energy Lab		25,000
	Extengine Transport Systems		22,500
	Combustion Components Assoc.		22,500
	Calif. Energy Commission		10,000
Term: 06/26/06 – 08/31/07	Total Cost:	$	280,000

Biodiesel is a renewable fuel derived from plant products. "Neat" or 100-percent biodiesel and biodiesel blends with petroleum diesel have demonstrated reductions in PM, CO, HC, and carcinogenic polyaromatic hydrocarbons (PAHs) from diesel engines. NOx emissions, however, have tended to increase. The City of Santa Monica is proposing to demonstrate various biodiesel blends in two refuse transfer trucks. Each truck will also be equipped with a commercial selective catalytic reduction (SCR) unit to reduce NOx emissions. Extensive emission testing will be performed with portable emission measurement equipment and at the CARB laboratory using a heavy-duty chassis dynamometer.

07020: California Air Resources Board

Contractor: California Air Resources Board (CARB)	SCAQMD Cost-share:	$	10,000
	Cosponsor:		
	CARB		10,000
Term: 08/30/06 – 04/30/07	Total Cost:	$	20,000

CARB is proposing new spark ignition engine emissions standards that will require advanced technology fuel systems that need a clean and consistent LPG fuel. The quality of LPG in California can vary considerably and may contain unacceptable levels of residual hydrocarbons that can foul advanced technology fuel systems. This project proposes to conduct an LPG sampling program throughout California focusing both on production and distribution facilities. About 100 samples are planned. The results will be used to assess the specifications for LPG fuel quality.

07054: Conduct In-Use Emissions Testing of Model Years 2004 & 2005 Classes 7-8 Heavy-Duty Diesel and Natural Gas Fueled Trucks

Contractor: West Virginia University	SCAQMD Cost-share:	$	240,000
Term: 12/13/06 – 08/15/07	Total Cost:	$	240,000

From 1990 through 2000, the on-road heavy-duty certification standards for NOx emissions decreased by approximately 20%. However, studies conducted by West Virginia University on 1990 through 2000 model in-use trucks showed that in-use NOx emissions generally did not decrease, and

that late 1990's trucks had even higher NOx emissions than early 1990's models. These results have implications for the on-road mobile source NOx emissions inventory. CARB has already revised its emissions factor model (EMFAC) to reflect the results of these studies. However, the implications of the Fleet Modernization Program have not been fully evaluated relative to replacing older diesel trucks with post-2003 heavy-duty diesel trucks. To further understand the in-use emissions levels of post-2003 heavy-duty trucks, in-use emissions testing will be conducted on fifteen 2004 and 2005 Class 7 and 8 heavy-duty diesel trucks.

Emission Control Technologies

01173: Advanced Diesel Fuels, Engines, NOx Absorber Catalyst & Diesel Particulate Filter Project for Heavy-Duty Engine Application

Contractor:	National Renewable Energy Lab (NREL)	SCAQMD Cost-share:	$	260,000
		Cosponsors:		
		U.S. DOE/NREL		125,000
		CARB		100,000
		Engine Control Systems		37,580
		Thermoking		30,000
Term:	06/11/01 – 08/31/07	Total Cost:	$	552,580

This project, added through a modification of the CRADA, is to assess the impact of gas-to-liquid (GTL) fuel and advanced emissions control systems on transportation refrigeration units (TRUs) operating in the South Coast Air Basin. The scope of the project includes the evaluation, quantification, and comparison of emissions from TRU diesel engines fueled with: (1) GTL fuel equipped with particulate filter, and (2) CARB specification conventional diesel fuel. U.S. DOE's NREL proposes selecting up to twelve TRU-equipped vehicles, six of the TRUs will be powered by GTL-fueled engines and retrofitted with particulate filters. The remaining six TRUs will be operated exclusively with CARB specification conventional diesel serving as control groups. One of the TRU engines will be tested over steady-state test procedures on an engine dynamometer while the engine is independently powered by GTL fuel and CARB diesel fuel. The result of this test and in-use field data logging of exhaust temperature and pressures from the test TRU engine will be used to develop and optimize a particulate filter system. The catalyst system will then be installed on four to six TRU engines. The same TRU engine will be again tested. The TRU-equipped vehicles will then be demonstrated in service for 6 to 12 months to evaluate performance, reliability, and the emission-reduction potential of the GTL fuel and particulate filter system.

Electric/Hybrid Technologies

06182: Develop & Demonstrate a Natural Gas Hybrid-Electric Transit Bus

Contractor: ISE Research Corp.	SCAQMD Cost-share:	$	200,000
	Cosponsors:		
	CARB (pass-through revenue)		100,000
	San Diego Metro		320,000
	San Diego APCD		180,000
	ISE Corporation		250,000
Term: 08/25/06 – 08/31/08	Total Cost:	$	1,050,000

ISE Corporation, along with the project partners, proposes to develop a hybrid drive system which will operate on compressed natural gas. As a part of this project, the 40-foot transit bus will use a smaller natural gas engine typically used in smaller 30-foot buses to further maximize the fuel economy benefits, as well as utilize the additional power available from the energy storage system. San Diego MTS will be providing a 40-foot New Flyer CNG glider (bus with no engine, transmission, and related equipment). ISE will develop, install and optimize a CNG hybrid drive system utilizing ISE's proven hybrid drive system using Siemens motors, inverters, and generators, and an ISE energy storage and vehicle control systems, modified to include a Cummins 5.9L ISB gas plus (CNG version). ISE will independently characterize the efficiency and emissions of the CNG engine to allow optimization of the hybrid drive system with this engine. The CNG hybrid bus will then be entered into revenue service by San Diego MTS for a minimum one-year period. The performance of this bus will be evaluated and compared to that of a conventionally powered CNG bus in a final report.

05260: Convert Light-Duty Vehicle to Plug-In Hybrid Electric

Contractor: EnergyCS	SCAQMD Cost-share:	$	130,000
	Cosponsors:		
	SCAQMD In-Kind Vehicles		116,000
	SMUD		85,500
	Manitoba Hydro		114,500
Term: 09/09/05 – 10/03/08	Total Cost:	$	446,000

In May 2005, the Governing Board approved co-funding to convert a 2005 Toyota Prius to a plug-in hybrid and demonstrate improved mileage including zero emissions range. In order to gain the necessary testing, mileage accumulation, and feedback from users prior to offering the technology as a commercial product, additional partners and vehicles are needed. This action is to amend the May 2005 award to include converting two additional hybrids with an option to convert another two hybrids with the next generation of refinements for demonstration by AQMD. Each hybrid converted in this amendment will cost $32,500 with AQMD also providing the hybrid vehicles for conversion. SMUD and Manitoba Hydro will each provide and demonstrate a vehicle as well as conduct battery and cold weather evaluations.

Engine Technologies

05244: Develop, Demonstrate & Certify Heavy-Duty Natural Gas Engine to Meet 2010 Emission Standards

Contractor: Cummins Westport, Inc.	SCAQMD Cost-share:	$	700,000
Term: 08/26/05 – 07/31/07	Total Cost:	$	700,000

In 2003, the Board approved the co-funding of a project to develop and test a natural gas stoichiometric, spark-ignited (SI) engine with a three-way catalyst (TWC) and exhaust gas recirculation (EGR) that would achieve the 2010 standards of 0.2 g/bhp-hr for NOx and 0.01 g/bhp-hr for PM. Cummins Westport successfully demonstrated the emission and performance targets for the 8.3L C Gas Plus engine as a part of that technology development project. Cummins Westport proposes to transfer and implement the technology developed under the earlier Cummins project to the L Gas Plus engine to meet the 2010 Federal standards for heavy-duty engines by 2007. The L Gas Plus is an 8.9L natural gas stoichiometric engine that has a peak rating of 320 HP and 1,000 lb-ft of torque. Cummins Westport plans to commercialize this engine in 2007, well ahead of the 2010 standards. Commercial availability of a heavy-duty engine at 0.2 g/bhp-hr NOx in 2007 will enable significant mobile source NOx reductions in comparison with model year 2007-2009 diesel engines. The original contract with the AQMD was for $690,000. However, it was anticipated the U.S. Department of Energy (DOE) would provide significant cost share, as indicated in the original contract. However, the DOE 2006 budget does not include any natural gas engine development, resulting in a significant shortfall for this project. Cummins Westport indicated that they are committed to commercialize heavy-duty natural gas engines meeting 2010 emissions standards as early as possible given the budgetary shortfalls, but could not guarantee commercializing the engines by early 2007 without additional funding assistance. Therefore, in April 2006 the Governing Board approved supplementing the original award with an additional $700,000 from the Clean Fuels Fund. The total cost to the AQMD is $1,390,000 for this project, with total cost of over $5.9 million, with the remainder from Cummins Westport and other project partners.

06033: Develop & Certify a Medium- and Heavy-Duty Natural Gas Engine

Contractor: John Deere Power Systems	SCAQMD Cost-share:	$	695,400
	Cosponsors:		
	National Renewal Energy Lab		508,789
	John Deere Power Systems		4,616,560
Term: 03/15/06 – 04/30/07	Total Cost:	$	5,820,749

John Deere Power Systems (Deere) proposes to utilize their 8.1L lean-burn natural gas Series 450 as a base engine and increase the bore and stroke to meet additional power growth requirements of larger transit and refuse applications, increasing the displacement to 9.0L. Additionally, Deere will add exhaust gas recirculation and three-way catalyst to the 9.0L version to achieve the 0.2 g/bhp-hr NOx and 0.01 g/bhp-hr PM standards, effective 2010. The new version is expected to continue to provide the current rated 250-280 hp, as well as providing increased horsepower up to 325hp. Furthermore, Deere proposes to certify the modified natural gas engine to the on-highway FTP standards, and field-test the modified engine in at least two fleets. Lastly, Deere plans to commercialize this technology in 2007, well ahead of the 2010 standards. Commercial availability of a heavy-duty engine at 0.2

g/bhp-hr NOx in 2007 will enable significant mobile source NOx reductions in comparison with model year 2007-2009 diesel engines. The contract with the AQMD is currently for $695,400 and was executed in 2006. However, it was anticipated the U.S. DOE would provide significant cost share, as indicated in the original contract. However, the DOE 2006 budget does not include any natural gas engine development, resulting in a significant shortfall for this project. Deere indicated that they are committed to commercialize heavy-duty natural gas engines meeting 2010 emissions standards as early as possible given the budgetary shortfalls, but could not guarantee commercializing the engines by the beginning of 2007 without additional funding assistance. Therefore, the Governing Board approved supplementing the original award with an additional $700,000 from the Clean Fuels Fund, but this modification has not yet been executed. Once it has, the total cost to the AQMD is not to exceed $1,395,400 for this project, with total cost of over $6.5 million, with the remainder from Deere and other project partners. The overall cost of the project has been reduced through cost-cutting measures by Deere.

06068: Develop & Demonstrate On-Board Diagnostic Systems for Natural Gas Vehicles

Contractor: Baytech Corporation	SCAQMD Cost-share:	$	319,615
	Cosponsors:		
	Texas Commission on Env. Quality		112,561
	General Motors		138,250
	Baytech Corporation		88,560
	Clean Energy		69,825
	BAF Technologies		46,085
Term: 01/20/06 – 01/30/07	Total Cost:	$	774,896

On-Board Diagnostic systems (OBDII) are required on light- and medium-duty vehicles to help identify and diagnose emission problems with the increasingly complex engines and emission controls of newer vehicles. Baytech Corporation is a small-volume manufacturer who has developed and certified CNG systems for GM vehicles for many years. Baytech Corporation will develop engine calibrations and perform emission testing to demonstrate OBDII compliance with their newest CNG system for General Motors full-size vans and cut-away vans. In addition, Baytech will certify the CNG vans for Model Year 2006.

Hydrogen Technologies and Infrastructure

06209: Develop & Demonstrate Heavy-Duty Hydrogen and Natural Gas Mixture Engine

Contractor: City Engines, Inc.	SCAQMD Cost-share:	$	500,000
	Cosponsors:		
	Los Angeles County MTA		500,000
	Trillium		In-Kind
	City Engines		In-Kind
Term: 08/30/06 – 08/30/08	Total Cost:	$	1,000,000

The majority of heavy-duty vehicles in the South Coast Air Basin are powered by diesel engines that contribute significant emissions of NOx and particulate matter. The AQMD has long recognized the adverse air quality and health impacts of diesel exhaust and has adopted several measures to promote the use of low-emission natural-gas vehicles. The Los Angeles County Metropolitan Transit Authority (MTA) has over 2,300 transit buses that operate on CNG. MTA is interested in evaluating various technologies that will help in complying with future CARB and U.S. EPA requirements, including the Zero Emission Bus program required under the Transit Bus Regulations. The MTA is currently evaluating a variety of technologies and strongly believe that HCNG mixture in ICEs with NOx aftertreatment will provide a demonstration of a bus with emissions below ambient levels, or a Zero-Emission Bus. MTA believes that this may be the most cost-effective zero emission propulsion system available in the near future. For this project, City Engines, Inc. proposes to modify an existing 11.0L Doosan engine to operate on a 30% mixture of hydrogen blended into natural gas, and demonstrate two transit buses on CNG and two on the HCNG mixture for a period of six months to evaluate the technology as well as quantify the emission benefits of HCNG mixture. City Engines will also seek emissions certification for this HCNG mixture ICE for transit bus use. Additionally, Trillium Fuel Systems, MTA's primary CNG supplier, will modify one of MTA's refueling facilities to allow for fueling the two buses with the HCNG mixture. Hydrogen will be supplied using a tube trailer. City Engines plans to commercialize this engine in future.

07033: Expand Reformer System & Upgrade Hydrogen Refueling Station in Coachella Valley

Contractor: SunLine Transit Agency		SCAQMD Cost-share:	$ 640,000
		Cosponsor:	
		SunLine Transit Agency	560,000
Term: 10/19/06 – 03/31/06		Total Cost:	$ 1,200,000

The AQMP has identified the use of alternative clean fuels in mobile sources as a key air quality management attainment strategy. Hydrogen vehicles have the potential to significantly reduce VOC, NOx, CO and toxic emissions as well as greenhouse gas emissions. Over the past five years, the AQMD, along with industry and state/federal agencies, has co-funded the development of initial hydrogen stations throughout the Basin. Most recently, the implementation of the five cities vehicle and station demonstration program has received state and national recognition for its development of fueling infrastructure and promotion of hydrogen vehicle technologies. AQMD continues to coordinate its hydrogen activities with the California Hydrogen Highway Network and the U.S. DOE. One of the initial five stations constructed a few years ago was in the Coachella Valley and utilized autothermal catalytic reformation of natural gas to generate hydrogen fuel for the buses and some light-duty vehicles at SunLine Transit. This contract will allow SunLine to upgrade its hydrogen refueling station and operate at least one zero-emission bus and possibly expand their fleet. It will also allow the refueling station to conform to the Hydrogen Highway Network guidelines and provide additional data gathering for a more robust, commercial-level refueling facility.

Mobile Fuel Cell Technologies

04126: Lease of One Additional Honda Fuel Cell Electric Vehicle

Contractor: American Honda Motor Company		SCAQMD Cost-share:	$ 12,990
Term: 06/22/04 – 07/23/07		Total Cost:	$ 12,990

This item is for the lease of a 2006 Honda fuel cell electric vehicle. The vehicle will be used in Technology Advancement's Alternative Vehicle Loan Program.

Health Impacts Studies

05172: Organic Compound Analyses of Particulate Matter Samples Collected Under MATES III

Contractor: Desert Research Institute		SCAQMD Cost-share:	$ 200,000
Term: 08/13/05 – 01/31/07		Total Cost:	$ 200,000

The Multiple Air Toxics Exposure Study (MATES) III Program was initiated in Spring 2004 to evaluate air toxic exposure trends, expand the list of known air toxics, and assess local impacts from industrial, commercial, and mobile sources. In October 2006 the AQMD Board allocated an additional $200,000 from Clean Fuels to conduct organic compound analyses of particulate matter samples collected under this Program.

Stationary Clean Fuel Technologies

06017: Field Demonstration of Advance Technology Boiler in South Coast District

Contractor: Gas Technology Institute		SCAQMD Cost-share:	$ 135,000
		Cosponsors:	
		Gas Technology Institute	204,104
		SoCalGas	40,000
		Clement Pappas (host site)	49,000
		Cleaver Brooks	49,000
Term: 03/15/06 – 12/15/07		Total Cost:	$ 612,146

The Gas Technology Institute (GTI) and Cleaver-Brooks have developed an advanced technology boiler, capable of 94% HHV fuel efficiency, which is can operate on natural gas with 5 ppmv NOx and CO (ref 3%O2) and is 50% smaller than conventional boilers of similar steam output. Furthermore, this performance is achieved at low excess air – less than 3% O2 – for optimal energy efficiency. This project is to achieve a California field demonstration of the fully developed technology in 2006-07. A commercial prototype boiler is to be installed and evaluated in normal operation at an industrial site within the SCAQMD's jurisdiction.

07017: Field Demonstration of 5-PPM FIR Ultra-Low NOx Burner on a Watertube Boiler

Contractor: Gas Technology Institute	SCAQMD Cost-share:	$	90,000
	Cosponsors:		
	SoCalGas		90,000
	Coen Company		120,000
Term: 10/19/06 – 07/18/07	Total Cost:	$	300,000

GTI and the Coen Company have developed an innovative ultra-low NOx burner capable of operation at less than 5 ppm NOx on large industrial boilers. This proposed project is to field-demonstrate the prototype burner on a working boiler at Cal-Tech. The technology offers additional advantages in terms of improved boiler efficiency and avoidance of ammonia-based NOx control. Since this technology is retrofitable to most boilers, there is also the potential to reduce emissions from the existing boiler population. The project will include a six-month testing and evaluation phase followed by transfer of operation to the host site and monitoring of performance for a minimum of two months. The proposed project includes a market study by the Coen burner company specifically addressing deployment of the technology in the South Coast Air Basin.

Outreach and Technology Transfer

04049: Technical Assistance for Alternative Fuels Engine Technology

Contractor: Engine, Fuel & Emissions Engineering Inc.	SCAQMD Cost-share:	$	60,000
Term: 11/21/03 – 12/31/07	Total Cost:	$	60,000

The AQMD currently has a contract with Engine, Fuel & Emissions Engineering, Inc. (EFEE). This funding will augment the existing contract with an additional $60,000 to provide technical expertise for natural gas engine technology. 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.

05008: Participate in California Fuel Cell Partnership for CY 2006 & Provide Support for Regional Coordinator

Contractor: Bevilacqua-Knight Inc.	SCAQMD Cost-share:	$	133,800
	Cosponsors:		
	8 automakers, 3 energy companies, 2 technology providers, 7 government agencies & 11 associate members		2,079,474
Term: 07/07/04 – 07/06/07	Total Cost:	$	2,213,274

In April 1999, the California Fuel Cell Partnership (CaFCP) was formed with eight members; AQMD joined and has participated since 2000. The CaFCP and its members are demonstrating fuel cell passenger cars and transit buses with associated 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. Subject to Governing Board annual review and approval, AQMD contributes $83,800 for membership, plus up to $50,000 and an office at AQMD to provide 50% support for the CaFCP Regional Coordinator.

05120: Technical Assistance for Technology Incentive Programs to Evaluate Proposals for Compliance

Contractor: Clean Fuel Connection, Inc.	SCAQMD Cost-share:	$	40,000
Term: 04/01/05 – 03/31/07	Total Cost:	$	40,000

The AQMD receives funding from state agencies to provide incentives for fleet operators to reduce emissions of construction equipment and medium- and heavy-duty vehicles. An important goal is to keep fleet operators, industry groups, and trade organizations apprised of emerging low and zero-emissions technologies and opportunities to purchase them. Although engine technology research is required to reduce the emissions at the combustion source, combustion cleanup methods are also needed to address the current installed base of on-road and off-road technologies. Clean Fuel Connection has assisted staff in project cost-effectiveness calculation and feasibility evaluation. This funding will augment an existing contract with Clean Fuel Connection.

05171: Technical Assistance on AB 1222 Advisory Group

Contractor: James Hazelton	SCAQMD Cost-share:	$	25,000
Term: 04/08/05 – 03/31/07	Total Cost:	$	25,000

James Hazelton is a respected expert in locomotives and railroad operations and is a resource to AQMD staff in evaluating technologies needed to meet future mobile source emission standards and potential AQMD rules, including the possible use of alternative fuels. Mr. Hazelton's experience in this field span the spectrum of locomotive research, testing, servicing and railroad operations. Mr. Hazelton has been appointed to the AB1222 Advisory Group for calendar year 2006. Assembly Bill 1222, chaptered on October 6, 2005, establishes the Remote Sensing Pilot Program, and requires the state board to implement a pilot program to determine emissions from locomotives using wayside remote sensing devices. The bill requires the state board to design and implement the pilot program in consultation with an advisory group established by the state board and consisting of specified members. The existing contract value was augmented to cover the expense of this new assignment.

06109: Update & Expand School Bus Inventory in Basin

Contractor: Burnett & Burnette	SCAQMD Cost-share:	$	50,000
Term: 04/13/06 – 04/12/07	Total Cost:	$	50,000

Exhaust emissions from high emitting diesel-fueled school buses are harmful to children and are a source of public exposure to toxic diesel particulate matter and smog-forming pollutants. There are thousands of older school buses on the road that have remained in service simply because school

districts lack funds to replace them. To reduce these emissions, the AQMD administers a Lower-Emission School Bus Replacement Program, which to date has awarded $55.7 million in local, state and federal funds to replace older diesel buses with new lower-emitting diesel or CNG buses, provide funding assistance to develop and enhance the alternative fuel infrastructure, and retrofit newer diesel-powered buses with particulate traps. Through a competitive bid, Burnett & Burnette was awarded a contract to update and expand the AQMD's existing school bus inventory originally developed in 2000. The survey results will assist the AQMD in better administering its Lower-Emission School Bus Replacement Program and replacing the oldest buses.

06147: Consulting Services in Preparation of Mobile Source Emissions Element of 2007 AQMP

Contractor: A 2nd Opinion, Inc.	SCAQMD Cost-share:	$	75,000
Term: 05/12/06 – 03/31/08	Total Cost:	$	75,000

The development of the 2007 AQMP Revision must be technically sound and withstand public scrutiny. Retaining outside technical expertise to assist staff in the development of the 2007 AQMP Revision is critical to an informed process. The experience and knowledge of A 2nd Opinion will provide significant benefits to the AQMD in the form of state-of-the-art understanding of oxygenated fuel issues and options, inventory uncertainties, air quality modeling analysis of specific fuel scenarios, and AQMD control measure design and analysis. The firm's principal, Mr. Cal Hodge, has extensive knowledge of oxygenated fuels, their underlying chemistry, the modeling protocols used by U.S. EPA and CARB to certify fuel formulations, the options available to refiners to achieve various levels of oxygenated blendstock and finished product, air quality models, emission data bases used to calibrate the CARB Predictive Model, refinery econometric optimization models as well as the regulatory foundation for past and current oxygenated fuels policy in California and nationally.

06161: Consulting Services in Preparation of Mobile Source Emissions Element of 2007 AQMP

Contractor: Saint Malo Solutions	SCAQMD Cost-share:	$	75,000
Term: 05/17/06 – 03/31/08	Total Cost:	$	75,000

The unique experience of Saint Malo Solutions will be very valuable in helping provide state-of-the-art input on the 2007 AQMP Revision's emissions inventory, underlying modeling, scenario construction and control measure development. Mr. Mark Carlock, the principal of Saint Malo Solutions, 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 2003 AQMP. Mr. Carlock has detailed knowledge of the key areas which need refinement and updating, and he already has the technical background and data needed to recommend specific changes and the basis for those changes in a timely manner as part of the upcoming AQMP revision.

06173: Administrative Assistance Services Related to Organization of International Conferences on Asthma and Port Emissions Control Technologies

Contractor: Maria Robles	SCAQMD Cost-share:	$	125,000
Term: 05/12/06 – 08/31/07	Total Cost:	$	125,000

Outreach efforts are critical to inform the public of health-related programs and keep people abreast of current technology, medical and scientific advances, and policy issues for topics such as goods movement, clean ports, and ultrafine particles. Ms. Maria Robles will provide administrative support for two air quality conferences: the International Conference on Asthma Impacts of Air Pollution scheduled for Spring 2007 and the Pacific Rim Ports Conference scheduled for Summer 2007. Ms. Robles demonstrated excellent abilities in securing sponsors and speakers in addition to event planning and miscellaneous administrative support when she assisted AQMD staff in organizing the highly successful Asthma Conference in 2006. In addition, her proposal contacted more project hours at the desired level of expertise.

06203: Technical Assistance for AQMD Ethanol Forum & Technical Roundtable

Contractor:	Harold Haskew & Associates, Inc.	SCAQMD Cost-share:	$ 5,000
Term:	06/25/06 – 06/30/06	Total Cost:	$ 5,000

The AQMD convened an Ethanol Forum and Technical Roundtable focused on the use of ethanol as a low-level blend component of gasoline and E-85 fuel ethanol for use in Flexible Fuel Vehicles. The objective of the meeting was to identify key expert perspectives on the energy and emission implications of the use of ethanol in order to identify appropriate oxygenate policy in the context of the upcoming revisions to the AQMP for the South Coast Air Basin. Key stakeholders were also invited, including auto manufacturers, energy companies, ethanol industry representatives, state and federal regulatory agencies, environmental and community organizations and other interested parties. Mr. Harold Haskew, who is now a private consultant on emission testing and modeling, following a 30+ year at General Motors, provided a technical overview presentation on his latest research and findings, along with responses to questions from participants at the Roundtable.

06217: Technical Assistance for AQMD Plug-In Hybrid Electric Vehicle Forum & Roundtable

Contractor:	Electric Power Research Institute	SCAQMD Cost-share:	$ 20,000
Term:	06/23/06 – 11/30/06	Total Cost:	$ 20,000

The AQMD convened a Plug-in Hybrid Electric Vehicle (PHEV) Forum and Technical Roundtable focused on the technical issues related to advanced batteries and their effect on the development and commercialization of PHEVs. The objective of the meeting was to identify key expert perspectives on battery capabilities, requirements, and other issues specifically for application to plug-in hybrid electric vehicles and to highlight important or necessary RD&D areas for near-term commercialization of plug-in hybrids. Dr. Mark Duvall of Electric Power Research Institute served as moderator for the Forum, and assisted AQMD staff in developing the Forum agenda. Dr. Duvall is a leading researcher in plug-in hybrid technology.

07012: Technical Assistance Related to the Air Quality Impact of Fuel Ethanol Usage

Contractor:	TIAX, LLC	SCAQMD Cost-share:	$ 100,000
Term:	09/15/06 – 08/31/08	Total Cost:	$ 100,000

Due to the significant growth in regional goods movement and the projected growth in the introduction of ethanol into transportation fuel usage, the AQMD believes the emissions and air quality impacts from these two activities are significant and need to be addressed expeditiously. External expertise is needed to address the air quality impacts and potential mitigation strategies related to fuel ethanol usage as staff prepares the 2007 AQMP Revision. Based on their experience and proposal, TIAX, LLC was awarded a contract through a competitive bid process to provide technical assistance related to the air quality impact of fuel ethanol.

07027: Technical Assistance for Air Quality Impacts & Mitigation

Contractor: Engine, Fuel & Emissions Engineering, Inc.	SCAQMD Cost-share:	$	25,000
Term: 09/29/06 – 08/31/08	Total Cost:	$	25,000

Again, the AQMD believes the emissions and air quality impacts of the regional goods movement needs to be addressed expeditiously. Also based on their expertise and proposal, EFEE was awarded a contract to provide technical assistance related to air quality impacts of regional goods movement and technology evaluation of potential mitigation.

07028: Technical Assistance for Air Quality Impacts & Mitigation of Regional Goods Movement

Contractor: TIAX, LLC	SCAQMD Cost-share:	$	50,000
Term: 09/21/06 – 08/31/08	Total Cost:	$	50,000

TIAX, LLC will provide technical assistance related to air quality impacts of regional goods movement and technology evaluation of potential mitigation. Mr. Jon Leonard, TIAX Project Manager, has over 24 years experience with low- and zero-emission mobile source technologies, emissions testing, and alternative fuel vehicles. TIAX, LLC also has experience in cargo handling equipment operations.

07044: Technical Assistance to Perform Web Editor Functions

Contractor: Chery Cooper	SCAQMD Cost-share:	$	2,901
Term: 09/22/06 – 09/21/07	Total Cost:	$	2,901

The AQMD maintains a sophisticated website and within the AQMD's website the Technology Advancement Office (TAO) has its own technical and detailed web pages. These funds were transferred to Information Management's budget to perform web editor functions associated with TAO's web pages. Chery Cooper has been the AQMD's Web Editor for several years. Upon her retirement in September 2006, the AQMD retained her under contract to continue these services.

07059: Technical Assistance Related to Air Quality Impacts for Regional Goods

Contractor: Dowling Associates, Inc.	SCAQMD Cost-share:	$	58,000
Term: 12/19/06 – 11/30/08	Total Cost:	$	58,000

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.

07060: Technical Assistance Related to Air Quality Impacts of Regional Goods Movement

Contractor: Don Breazeale and Associates, Inc.		SCAQMD Cost-share:	$ 58,000
Term: 11/15/06 – 11/30/08		Total Cost:	$ 58,000

Along with Dowling Associates above, the AQMD awarded a contract to Don Breazeale and Associates to provide technical assistance related to air quality impacts of regional goods movement. Their experience includes knowledge of shipping lines and landslide operations.

07062: Technical Assistance Related to Air Quality Impacts of Regional Goods

Contractor: The Tioga Group, Inc.		SCAQMD Cost-share:	$ 58,000
Term: 12/19/06 – 11/30/08		Total Cost:	$ 58,000

Along with Dowling Associates and Don Breazeale Associates above, the AQMD awarded a contract to The Tioga Group, Inc. to provide technical assistance related to air quality impacts of regional goods. The Tioga Group has primary expertise in rail and landslide operations. And all three firms have provided consulting services in the past to the ports in California, California Department of Transportation, and Southern California transportation agencies.

07129: Technical Assistance with Fuel Cell Technology

Contractor: Breakthrough Technologies Institute, Inc.		SCAQMD Cost-share:	$ 40,000
Term: 12/01/06 – 03/31/08		Total Cost:	$ 40,000

Breakthrough Technologies will provide expertise with federal funding allocations, fuel cell technology and administrative coordination with federal agencies, including U.S. DOE and U.S. Department of Transportation, with funding in an amount not to exceed $40,000. Mr. Robert Rose, Executive Director of Breakthrough Technologies Institute and founding Executive Director of the U.S. Fuel Cell Council, will provide specialized support to the AQMD with his technical expertise in commercialization of fuel cells and other low- and zero-emission technologies.

07175: Technical Assistance for Container Movement Forum and Roundtable

Contractor: Network Public Affairs, LLC	SCAQMD Cost-share:	$	11,000
Term: 12/26/06 – 07/31/07	Total Cost:	$	11,000

The emissions from locomotives, trucks and other related equipment used to transport cargo are significant contributors to the air pollution and toxic risk affecting the residents of the South Coast Air Basin. The AQMD is pleased to host this one-day technology forum and roundtable discussion of the current and upcoming technologies which could reduce or eliminate these harmful emissions. Ms. Nancy Pfeffer has 25 years of environmental and transportation public policy experience. Ms. Pfeffer will assist in the planning and coordination of this AQMD event. She will serve as moderator for the Roundtable discussion and will summarize the salient results in a report.

Fund Transfer: Conduct & Host International Clean Ports Conference in Spring 2007

Contractor: n/a	SCAQMD Cost-share:	$	150,000
Term: 07/14/06	Total Cost:	$	150,000

In 2006 the Chairman of the Board presented the Clean Port Initiative Workplan intended to achieve more rapid reductions of port emissions. The Ports of Long Beach and Los Angeles are the largest emission sources in the South Coast basin with cumulative emissions from the marine vessels, harbor craft, cargo handling equipment, locomotive, and trucks operating to, from and within the ports. As part of the Workplan, the AQMD will conduct an international conference between Southern California and Asian ports to provide a focal point for ports along the Pacific Rim to discuss strategies and work in a joint effort to reduce emissions from ocean-going ships as well as in-port emissions. To this end, the Board authorized up to $150,000 to organize and conduct the International Clean Ports Conference, which will be conducted sometime in 2007. The monies were simply transferred from the Clean Fuels Fund into this special fund.

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

Contractor: Various Contractors	SCAQMD Cost-share:		$	145,655
	Cosponsors:			
		Various		795,345
Term: Various	Total Cost:		$	941,000

The SCAQMD regularly participates in and sponsors conferences, workshops and events. These funds provide support for 14 events during 2006, plus two business council memberships.

PROGRESS IN 2006

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 advancements in engine design, electric power trains, energy storage/conversion devices (e.g., fuel cells and batteries); and 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 NOx technologies and clean energy alternatives, such as fuel cells, solar power, and other renewable energy systems.

Table 4 provides a list of projects completed in 2006; summaries of these completed projects are included in Appendix C. Selected projects which represent a range of key technologies from near-term to long-term are highlighted below.

Gas-to-Liquid Fueled Heavy Duty Vehicles

Gas-to-liquid (GTL) or Fischer-Tropsch (FT) fuels are an attractive alternative to diesel because they can be used in conventional applications but have low aromatic content and near-zero sulfur content. Previous tests in unmodified heavy-duty trucks have shown that 100% F-T fuels combust more cleanly and produce lower engine-out emissions of NOx (>6%), VOC, PM (>24%), and carcinogenic pollutants than CARB diesel fuel.

The goal of the project completed by Automotive Testing Laboratories was to demonstrate further emissions reduction using a system approach—advanced fuels, improved combustion, and state-of-the-art catalyst systems. The emissions targets for this project were (cold and hot start composite) 1.2 g/bhp-hr NOx, 0.01 g/bhp/hr PM, 1.3 g/bhp-hr HC, 15.5 g/bhp-hr CO, and 0.4 g/bhp-hr NO2. The emissions demonstration was planned over the U.S. Heavy Duty Transient test cycle and an 8-mode steady state test.

To achieve the project emission targets, both combustion system modifications and an exhaust emission control system were implemented. Combustion system modifications included a custom piston bowl design, wider fuel injection angle, and increased EGR flow rate. These changes were specifically incorporated to reduce NOx emissions and were enabled by the ignition properties of the GTL fuel. NOx emissions measured over the FTP cycle were reduced by over 25% as a result of the combustion modifications. The advanced aftertreatment system included a NOx reduction catalyst and a diesel particulate filter, which were enabled by the near-zero sulfur content of GTL fuel. In the engine test cell, the combination of engine combustion system modifications, exhaust emission control system and GTL fuel yielded exhaust emissions lower than the program's target values.

Upon completion of modifications and testing, the engines and aftertreatment systems were installed in two Class 8 delivery trucks to assess their durability and performance. Chassis dynamometer testing was performed on these vehicles over both transient and steady state test cycles representative of typical truck applications, including simulating a truck hauling a fully loaded trailer. The test vehicles with the modified engines and emission control systems were then subjected to a durability demonstration with both retrofitted trucks performing routine delivery service for a period of six months.

Figure 9: Class 8 Truck with Modified Engine

The new technology in the modified trucks was sufficiently robust to meet delivery demands over the test program, and driver comments were consistently positive, particularly in regard to hill-climbing power. System durability suffered from integrating an experimental engine and aftertreatment system into a chassis that was not designed for them, which prevented a more complete evaluation of the technology. Future demonstrations should involve vehicle integration issues during the planning stages. The engine modifications and emission control system in combination with the GTL fuel yielded exhaust emission reductions of over 40% for NOx and over 90% for PM with only a 4% reduction in fuel economy. This project demonstrated that the unique properties of GTL fuel, namely the very high cetane number, low aromatics, and extremely low sulfur content, can help engines and aftertreatment systems meet increasingly stringent emission standards.

PM & Hydrocarbon Emissions Control of CNG-Fueled Heavy-Duty Engines

This project targeted the development and optimization of catalyzed particulate filters (PF) to further reduce particulate matter and hydrocarbon emissions by at least 60 percent without increasing NOx, CO, and toxic pollutants emissions from CNG-fueled heavy-duty engines. In addition, this project investigated the impact of lubricants on emissions from CNG engines, and assessed emission-reduction potential, performance, and reliability of the catalyzed particulate filters during a six-month in-use demonstration program.

In this project, a Cummins Westport C Gas Plus engine was tested on an engine dynamometer while the engine was independently equipped with (1) a standard oxidation catalyst, (2) a standard coated wall-flow Engelhard DPX filter, and (3) a wall-flow filter configured to match the characteristics of natural gas engine exhaust emissions. Westport Research used the result of the tests and in-field data logging of exhaust pressures and temperatures from the test bus to develop and optimize a catalyst particulate system. The catalyzed particulate control system was installed at the exhaust of a transit bus and tested over transient and steady state cycles on a chassis dynamometer. The bus was demonstrated in service for six-months to evaluate performance, reliability, and emission-reduction potential of the particulate filter.

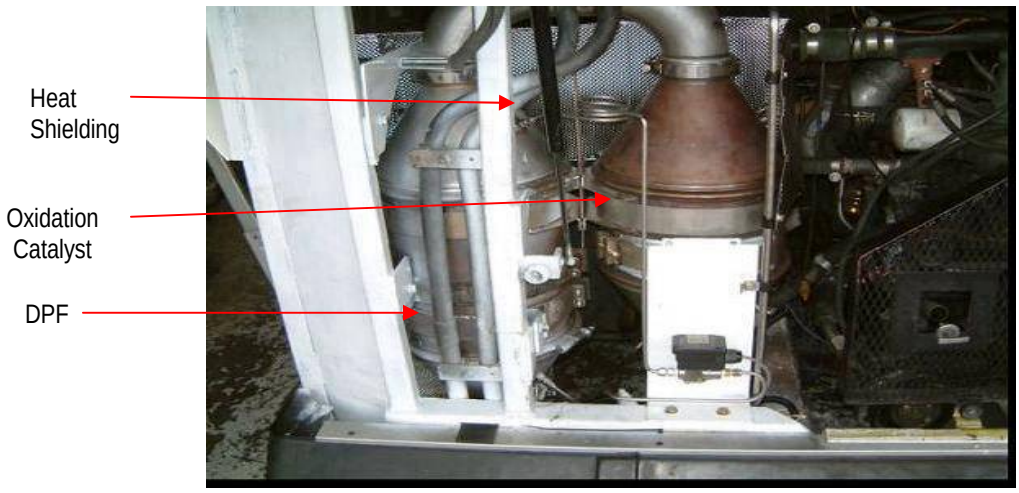


Figure 10: Detailed View of Installed Aftertreatment System

The final configuration for the aftertreatment system with PF included was selected from a number of potential configurations using data gained from testing completed at Westport Innovations. The work consisted of performing steady state testing to establish baseline emissions from the C Gas Plus with no aftertreatment and with the standard C Gas Plus oxidation catalyst. The various configurations of aftertreatment were tested over the same steady state points to evaluate their comparative performance with respect to non-methane hydrocarbon (nmHC), methane (CH_4), and particulate matter emissions (PM). The PF were also subjected to a 100-hour duration test at various engine conditions, before and after which the physical weight of the filter was measured to evaluate the PM accumulation in the filter. This data allowed selection of the aftertreatment configuration for the next phase of work.

The final configuration selected for vehicle test phase used the standard C Gas Plus oxidation catalyst along with the uncoated Engelhard DPF. This combination had the highest conversion of nmHC and CH_4, low PM accumulated mass on the steady state test and low PM accumulation over the 100-hour test. The chosen system was fitted to a 40-foot transit bus supplied by SunLine Transit, based near Palm Springs, California. The bus was placed in revenue service for 6 months and covered over 30,000 miles during the demonstration period.

Figure 11: SunLine Bus 531 in Service

At the start of the field trial a test program was completed on this vehicle at the West Virginia University mobile laboratory, based in Riverside, California. The University of Wisconsin and University of Minnesota were present to take measurements for the following:

- Gravimetric analysis of PM_{10}, $PM_{2.5}$, PM_1 and total PM.
- Aerosol concentrations and size distributions.
- Volatile hydrocarbons (C2-C10), methane, CO and CO2 using gas chromatography (GC) techniques.
- Gas-phase carbonyls using liquid chromatograph techniques.

- Particle-phase water-soluble ions by ion-chromatography.
- Gas and particle-phase polycyclic Aromatic Hydrocarbon (PAH) by gas chromatography mess spectrometry.
- Particle-phase PAH by Nitro-PAH gas chromatography mass spectrometry.
- Particle-phase trace metals by inductively coupled plasma mass spectrometry, inductively coupled plasma and liquid waveguide-enhanced optical spectro-photometry techniques.

Testing was completed to compare three different ages of engine lubrication oil, these being new, mid-life and end-of-life. The initial testing was completed with the standard engine oxidation catalyst fitted. From these oils the "worst case" oil was chosen based on preliminary results for particulate mass and number. Further testing was completed with the chosen oil but with the particulate filter fitted to the exhaust system of the test vehicle to establish the effect that the PF has on the particulate emissions.

The test cycles completed in this testing included 3 steady state modes (idle, 20mph and 40mph) along with the transient Central Business District (CBD) cycle. The results from the testing in standard configuration showed that the C Gas Plus engine has very low particulate emissions on a mass and particulate number basis. The results also showed that particulate emissions (number and mass) to increase with oil age. Thus, the end-of-life engine oil was used for the final testing with the particulate filter fitted. This testing showed that the particulate filter did have an effect of lowering the emissions on a particle number/count basis. For example, in start-up conditions, it appeared that the particulate filter captured the initial spike observed in tests without the particulate filter fitted. In some cases the particle number observed with the particulate filter were two orders of magnitude lower than that with just the oxidation catalyst.

Compressed Hydrogen Production and Refueling Station at LAX Airport

The AQMD, in partnership with Praxair, BP, U.S. DOE and CEC, installed a hydrogen generation and fueling station at LAX. The station uses electrolysis of water to produce the hydrogen at a maximum rate of one kg/hr with the capability of a fast-fill mode of 5 kg/5 min or a slow-fill mode of 0.25 kg/min. The hydrogen produced is cleaned and dried then compressed and stored at up to 5000 psi in four cascade-type storage tanks. Maximum storage capacity is 80 kg with a usable high pressure delivery of about 45 kg. This system is used by the LAX/DaimlerChrysler fleet and is available for outside users from other demonstration programs at various facilities nearby.

The electrolyzer station produces no emissions of NOx, CO, or CO2. The main tradeoff of this system is the electrical power required to operate the system. The cost of this power can be significant and the emissions from the power generation systems producing the power must also be considered. The hydrogen fuel quality has been tested by several different entities and has been shown to meet the needs of various fuel cell and vehicle manufacturers.

Future plans for the station include possible expansion of the storage capacity to accommodate delivered hydrogen to support a proposed hydrogen-powered shuttle bus fleet demonstration at the airport. This will allow for the introduction of higher fuel use vehicles such as the shuttle buses at the site.

Figure 12: LAX Skid & Electrolysis Unit

Table 4: Projects Completed Between January 1 and December 31, 2006

Contract	Contractor	Project Title	Date
Incentive Programs-Alternative Fuels			
00105†	Avery-Dennison Office Products North America	Purchase Nine Electric Forklifts	Mar-06
00107†	Harbor Distributing, LLC	Purchase 32 Electric Forklifts	Mar-06
00113†	Lowe's Home Improvement Warehouse Inc.	Purchase 40 Electric Forklifts	Mar-06
00131†	Homebase Inc.	Purchase 20 Electric Forklifts	Mar-06
01137†	R.F. Dickson Company, Inc.	Repower Ten & Purchase Four PM10 Efficient CNG Street Sweepers	Dec-06
01138†	Hayward Pool Products, Inc.	Purchase Two Electric Forklifts with Batteries	Jun-06
01336†	Chroma Systems	Purchase Electric Forklift with Battery	Jun-06
Fuels/Emission Studies			
05069†	Automotive Development & Testing Services	Evaporative Emission Testing of Gasoline Hybrid-Electric Bus	Jun-06
Emission Control Technologies			
02293	Automotive Testing Laboratories	Develop & Demonstrate Fischer Tropsch Fueled Heavy-Duty Vehicles with Control Technology to Reduce Exhaust Emissions	Jun-06
03467	Westport Research Inc.	Develop & Demonstrate Aftertreatment Technology for PM & Hydrocarbon Emissions Control of CNG-Fueled Heavy-Duty Engines	Apr-06
05195	West Virginia University Research Corporation	Provide Transportable Emissions Testing of CNG-Fueled Heavy-Duty Engines	Jul-06
Electric/Hybrid Technologies			
00051	Santa Barbara Electric Bus Works, Inc.	Develop & Demonstrate an Electric School Bus	Feb-06
04143	Clean Fuel Connection, Inc.	Public EV Charging Equipment & Signage Replacement	Jul-06
Engine Technologies			
05110	Westport Research Inc.	Develop Heavy, Heavy-Duty Natural Gas Engine for Class 8 Trucks	Jun-06
05161	BAF Industries	Develop & Certify Natural Gas-Powered Ford Vehicles	Sep-06

Table 4: Projects Completed Between January 1 and December 31, 2006 (Cont'd)

Contract	Contractor	Project Title	Date
Hydrogen Technologies and Infrastructure			
03198	Praxair Inc.	Develop & Demonstrate Electrolyzer-Based Hydrogen Fueling Station Near LAX	Jan-06
04012	Stuart Energy	Install & Demonstrate Electrolyzer-Based Hydrogen Refueling Station in Diamond Bar	Apr-06
Mobile Fuel Cell Technologies			
03269	University of California Davis	Develop, Demonstrate & Evaluate Truck Fuel Cell Auxiliary Power Unit	Jul-06
03287	California Air Resources Board	Develop & Demonstrate Integrated Autothermal Cyclic Reformer and PEM Fuel Cell	May-06
Health Impacts Studies			
03358†	Jurupa Unified School District	Children's Asthma-Air Quality Health Study	May-06
Stationary Clean Fuel Technologies			
06075	Advanced Engine Technology Corporation	Field Comparison of Portable Electrochemical Analysers to a CEMs for Measurement of NOx and CO Emissions from a Rich-Burn Engine	Aug-06
Outreach and Technology Transfer			
00098†	Murray Katz	Technical Assistance Pertaining to Fuel Cell Development & Commercialization	Feb-06
03451†	TIAX LLC (formerly Arthur D. Little)	Technical Assistance Pertaining to AQMP Revision & Mobile Source Control Sources	Nov-06
04051†	Burnett & Burnette	Technical Assistance for Alternative Fuels Engine Technology & Infrastructure	Jul-06
04052†	USA Pro & Associates	Technical Assistance for Alternative Fuels Infrastructure	Dec-06
04115†	Los Altos High School	Cosponsor the LAAE Ultra-Light Single Passenger Fuel Cell/Electric Powered Vehicle Project	May-06
04168†	Regulus Associates Inc.	Technical Assistance on Contract-Related Services	Jun-06
05137†	City of Sierra Madre	Cosponsor the Solar Pool Heating System Demonstration Project	Mar-06
05149†	Clean Vehicle Education Foundation	Cosponsor 2005 Clean Vehicle Education Foundation Activities	Apr-06
05190†	Walnut High School	Cosponsor Walnut High School Car Project	Mar-06
06016†	University of California, Riverside	Cosponsor the ISAF XV International Symposia on Alcohol Fuels	May-06
06020†	Gladstein, Neandross & Associates LLC	Co-Host 2nd Faster Freight, Cleaner Air 2006 Conference	Sep-06

Table 4: Projects Completed Between January 1 and December 31, 2006 (Cont'd)

Contract	Contractor	Project Title	Date
Outreach and Technology Transfer (cont'd)			
06046†	Weststart-Calstart	Cosponsor 6th Annual Clean Heavy-Duty Vehicle Conference	Sep-06
06051†	National Hydrogen Association	Cosponsor 17th Annual U.S. Hydrogen Conference	Oct-06
06053†	Westart-Calstart	Cosponsor 6th Annual Clean Heavy-Duty Vehicle Conference	Sep-06
06054†	Western Riverside Council of Governments	Cosponsor 7th Annual WRCOC's Advancing the Choice Event	May-06
06092†	Southern California Association of Governments	Cosponsor SCAG's Energy Conference	Aug-06
06098†	Coordinating Research Council Inc.	Cosponsor 16th Annual CRC On-Road Vehicle Emissions Workshop	Sep-06
06117†	Air & Waste Management Association	Cosponsor the AWMA Climate Conference	Mar-06
06162†	California Climate Action Registry	Cosponsor CaCAR's 4th Annual Conference	Oct-06
06203†	Harold Haskew & Associates Inc.	Technical Assistance for AQMD Ethanol Forum & Technical Roundtable	Jun-06
06210†	American Society of Mechanical Engineers	Cosponsor 4th ASME Conference on Fuel Cell Science, Engineering & Technology	Oct-06
06217†	Electric Power Research Institute	Technical Assistance for AQMD Plug-In Hybrid Electric Vehicle Forum & Roundtable	Nov-06

†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.

FUTURE TECHNOLOGIES

Funding Priorities for 2007

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_x 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 2007 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 2009. 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 2010 or later.

- More mature technologies, those ready to begin field *demonstration* in 2007, are expected to result in a commercial product in the 2008-09 timeframe. Technologies being

field demonstrated generally have been certified or 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 the role of governments 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 require initial support and funding.

Summary of Technical Priorities

The SCAQMD program maintains flexibility to address dynamically evolving technologies and 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, given the funding 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 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 funding for purchasing natural gas vehicles is 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

- Early commercial deployment of alternative fuel light-duty vehicles

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
- 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. And 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 catalysts)
- Development and demonstration of low VOC and PM lubricants for diesel and natural gas engines
- 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
- 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_x 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 locomotives
- 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 ICEs for vehicle and power applications

- Development and demonstration of hydrogen HCNG vehicles for medium- and heavy-duty applications
- 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 much 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 2007 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 vehicle to grid power and fuel cell auxiliary power units)
- Development and demonstration of fuel cells in off-road and marine applications
- 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_x, 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_x burners, fuel cells, or microturbines), and
- Evaluation, development, and demonstration of advanced control technologies for miscellaneous stationary sources

Target Project Allocations

Figure 13 below presents the potential allocation of available funding, based on SCAQMD projected program costs of more than $22 million for all potential projects. The expected actual project expenditures for 2007 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 2007 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.

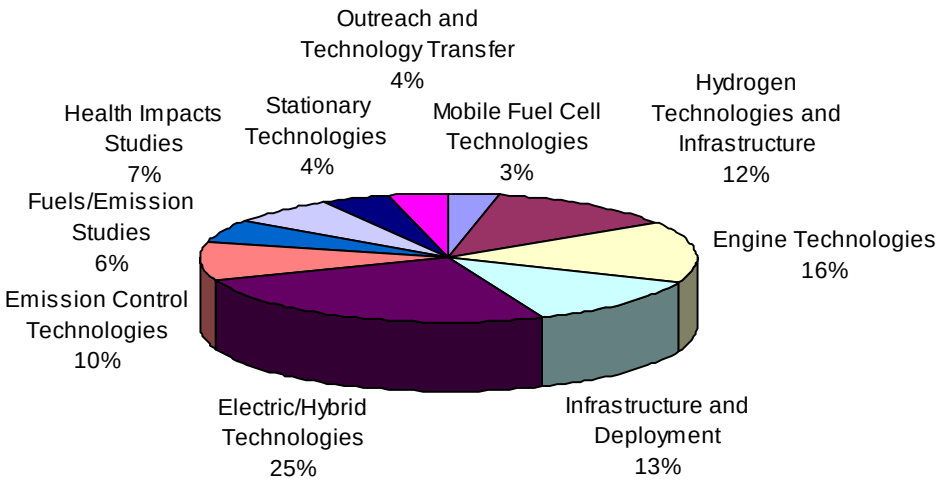


Figure 13: Projected Cost Distribution for Potential SCAQMD Projects 2007 & Beyond ($22M)

PROGRAM PLAN UPDATE

This section presents the Clean Fuels Program Plan Update for 2007. 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 5.

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 5: Summary of Potential Projects

Proposed Project	Expected SCAQMD Cost	Expected Total Cost
Infrastructure and Deployment		
Develop and Demonstrate Biofuels in Vehicles	1,000,000	5,000,000
Demonstrate Equipment to Reduce Fugitive Fueling Emissions	100,000	400,000
Upgrade of Existing Natural Gas Infrastructure	250,000	1,000,000
Develop and Demonstrate Advanced Natural Gas Systems for Refueling Stations	750,000	4,000,000
Demonstrate LNG Manufacturing and Distribution Technologies	750,000	7,000,000
Subtotal	$2,850,000	$17,400,000
Fuels/Emission Studies		
Conduct Studies to Develop More Accurate Emissions Inventories	500,000	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	$1,250,000	$4,300,000
Emission Control Technologies		
Develop and Demonstrate Advanced Aftertreatment Technologies	2,000,000	5,200,000
Demonstrate Proven Clean Technologies in Off-Road and Retrofit Applications	250,000	1,000,000
Subtotal	$2,250,000	$6,200,000
Electric/Hybrid Technologies		
Demonstrate Light-Duty Plug-In Hybrid Electric Vehicles	3,000,000	5,000,000
Develop and Demonstrate Medium- and Heavy-Duty Hybrid Vehicles and Systems	1,000,000	5,000,000
Demonstrate Alternative Energy Storage	750,000	2,600,000
Transfer and Demonstrate Hybrid and Electric Technologies to Conventional Applications	150,000	500,000
Develop and Demonstrate Electric Container Transport Technologies	750,000	5,000,000
Subtotal	$5,650,000	$18,100,000
Engine Technologies		
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	1,000,000	5,000,000

Table 5: Summary of Potential Projects (Cont'd)

Proposed Project	Expected SCAQMD Cost	Expected Total Cost
Engine Technologies (cont'd)		
Develop and Demonstrate Clean Container Transport Technologies	$1,500,000	$5,000,000
Subtotal	$3,500,000	$14,000,000
Hydrogen Technologies and Infrastructure		
Develop and Demonstrate Hydrogen Storage Technologies	$250,000	$1,000,000
Develop and Demonstrate Hydrogen Vehicles	500,000	2,000,000
Develop and Demonstrate Distributed Hydrogen Production and Fueling Stations	2,000,000	9,000,000
Subtotal	$2,750,000	$12,000,000
Mobile Fuel Cell Technologies		
Develop and Demonstrate Fuel Cells in Vehicle Applications	750,000	3,500,000
Subtotal	$750,000	$3,500,000
Health Impacts Studies		
Evaluate Ultrafine Particle Health Effects	$750,000	$3,000,000
Conduct Monitoring to Assess Environmental Impacts	500,000	1,000,000
Assess Sources and Health Impact of Particulate Matter	300,000	300,000
Subtotal	$1,550,000	$4,300,000
Stationary Clean Fuel Technologies		
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	500,000	1,000,000
Subtotal	$1,000,000	$2,250,000
Outreach and Technology Transfer		
Assessment and Technical Support of Advanced Technologies and Information Dissemination	500,000	500,000
Support for Implementation of Various Clean Fuels Vehicle Incentive Programs	400,000	400,000
Subtotal	$900,000	$900,000
TOTALS FOR POTENTIAL PROJECTS	**$22,450,000**	**$82,950,000**

Infrastructure and Deployment

Proposed Project: Develop and Demonstrate Biofuels in Vehicles

Expected SCAQMD Cost: $1,000,000

Expected Total Cost: $5,000,000

Description of Technology and Application:

The use of biological feedstocks for fuels, e.g., waste products (biomass), cellulosic biomass (ethanol), and organically derived oils (biodiesel), is a continuing goal due to their renewable and sustainable potential. Such fuels, however, must also provide prospective economic production, seamless integration with current vehicle technologies, and low emissions in order to be competitive in the marketplace. This project category is to demonstrate biofuels in vehicles in order to investigate these challenges. Existing and advancing technologies may be used in concert with the fuels to enable lower production costs, maintain vehicle performance, and reduce emissions to the lowest possible levels. Potential feedstock candidates include refuse sites, water reclamation facilities, diaries, and greenwaste collection facilities. Conversion processes may include gasification, celluosic, or photobiological.

The resulting alternative fuels to be demonstrated under this project category include methane (CNG), hydrogen, ethanol, Fischer-Tropsch, and biodiesel.

Potential Air Quality Benefits:

This project category is to ensure that renewable transportation fuels do not adversely affect air quality for the sake of sustainability. For example, although biodiesel and ethanol have been supported at the federal level, these fuels have potentially adverse air quality issues in the South Coast Air Basin. Biodiesel has lower PM but higher NO_x emissions than conventional diesel, and ethanol at low concentrations has potentially higher VOC emissions but does not meet SULEV NO_x emissions. This project category would investigate technologies to enable these fuels to provide both the lowest possible emissions with the renewable and petroleum reduction benefits.

Proposed Project: Demonstrate Equipment to Reduce Fugitive Fueling Emissions

Expected SCAQMD Cost: $100,000

Expected Total Cost: $400,000

Description of Technology and Application:

Fugitive emissions are difficult to identify, quantify, and capture. For example, propane emissions from BBQ, residential, forklift, automotive, commercial, industrial, etc. are estimated to leak approximately seven tons of VOC emissions per day into the atmosphere within the South Coast Basin. This project category is to identify and develop equipment to reduce the fugitive emissions from a variety of refueling and storage equipment (e.g., above-ground tanks and under-ground tanks); processing and transfer (e.g., valves, pumps, compressors, etc.) of chemicals and petroleum products; and gasoline dispensing facilities. Projects in this category will focus on new technologies to detect and repair frequent and big leaks, develop leakless valves, and enhance vapor recovery devices to broaden their applications and/or to improve control efficiency.

Potential Air Quality Benefits:

VOC emission reductions are required in the Basin to attain federal Clean Air Standards. Projects in this category will target long-term technologies and processes that, if successful, will result in direct VOC emissions reductions at the demonstration sites, followed by broader applications that can deliver major VOC reductions throughout the Basin from the emission sources listed above.

Proposed Project: Upgrade of Existing Natural Gas Infrastructure

Expected SCAQMD Cost: $250,000

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, natural gas-fueled vehicles (NGVs) initially in private and public fleets in the area. Such increased penetration of NGVs will provide direct emissions reductions of NO_x, 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: $750,000

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_x, VOC, CO, PM, and toxic compound emissions from mobile sources.

Proposed Project: Demonstrate LNG Manufacturing and Distribution Technologies

Expected SCAQMD Cost: $750,000

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 2010. 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_x, PM, and toxic compound emissions.

Fuels/Emission Studies

Proposed Project: Conduct Studies to Develop More Accurate Emissions Inventories

Expected SCAQMD Cost: $500,000

Expected Total Cost: $1,300,000

Description of Technology and Application:

In order to develop more accurate predictive models, the SCAQMD regularly sponsors studies to help upgrade the emissions inventory of various mobile sources. For example, a study was cosponsored with CARB in 1990 to update the emission inventory from locomotives for development of the 1994 AQMP. Similarly, in 1999 a study was sponsored to update the marine vessels emissions inventories for the 2003 AQMP. Both studies provided emissions inventories for various categories of locomotives and marine vessels (ocean-going vessels and harbor craft) for the 1994 and 1997 base years and forecast years (2000, 2010, and 2020). The emissions inventories presented a significant improvement compared to the inventories previously developed.

Current information indicates significant increases beyond previous projections in many different sectors, particularly marine vessels, locomotives, cargo handling equipment, and other non-road applications. This new information needs to be analyzed and integrated into new emission inventory projections.

Potential Air Quality Benefits:

Updated emissions inventories in the Basin are necessary for the purpose of planning and development of the 2007 AQMP Revision. Further improvements to the existing emissions inventories and future growth projections are critical to accurately assess the air quality impacts from the ports as well as planning future controls necessary to demonstrate attainment of the 8-hour ozone and PM2.5 national ambient air quality standards.

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)
- 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 AQMP as a potential control strategy.

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.

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_x Engines" and M5, "Heavy-Duty Diesel Vehicles; Additional NO_x 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_x 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_x, 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 SCR and NO_x adsorbers, could also have NO_x reductions of up to 90%.

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

Expected SCAQMD Cost: $250,000

Expected Total Cost: $1,000,000

Description of Technology and Application:

Heavy-duty on-road engines have demonstrated progress in meeting increasingly stringent Federal and state requirements. New heavy-duty engines have progressed from 2 g/bhp-hr NOx in 2004 to a targeted 0.2 g/bhp-hr NOx in 2007, which is an order of magnitude decrease in just three years. Off-road engines, however, have much higher emissions limits depending on the engine size. For example, Tier-3 standards, which took effect in 2006, require only 3 g/bhp-hr NOx. There are apparent opportunities to implement cleaner on-road technologies in off-road applications. There is also an opportunity to replace existing engines in both on-road and off-road applications with the cleanest available technology. Current regulations require a repower (engine exchange) to only meet the same emissions standards as the engine being retired. Unfortunately, this does not take advantage of recently developed clean technologies.

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

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

- Demonstrating certified LNG and CNG on-road engines in off-road applications including yard hostlers, switcher locomotives, gantry cranes, waste haulers, and construction equipment;
- Implementing lower emission engines in repower applications for both on-road and off-road applications; and
- 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: $3,000,000

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 AQMD 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 (PHEV) 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 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.

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

Expected SCAQMD Cost: $1,000,000

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 the 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 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: $750,000

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 retroffitable 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 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: 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 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: $750,000

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 AQMP proposes to reduce emissions from this activity by modernizing the fleet and retrofitting NOx and PM emission controls on older trucks. An alternative approach, especially for local drayage to the nearby intermodal facilities, is to use advanced container transport systems. 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 Medium- and Heavy-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_x 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; and
- Development of durable and reliable retrofit technologies to convert engines and vehicles from petroleum fuels to alternative fuels.

Anticipated fuels for these projects include but are not limited to CNG, LNG, LPG, emulsified diesel, and gas-to-liquid (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_x. 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: $1,000,000

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 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.

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 liquefied natural gas (LNG), compressed natural gas (CNG), selective catalyst reduction (SCR), particulate filters including diesel particulate filters (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 trailered, 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 AQMP proposes to reduce emissions from this activity by modernizing the fleet and retrofitting NOx and PM emission controls on older trucks. An alternative approach 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.

Hydrogen Technologies and Infrastructure

Proposed Project: Develop and Demonstrate Hydrogen Storage Technologies

Expected SCAQMD Cost: $250,000

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 is the subject 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 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: $500,000

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 internal combustion engine (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 is a high priority under the 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: $2,000,000

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 station 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 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_x, 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: $750,000

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 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 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.

Health Impacts Studies

Proposed Project: Evaluate Ultrafine Particle Health Effects

Expected SCAQMD Cost: $750,000

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 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: $500,000

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, railyards, 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 AQMD 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: $300,000

Expected Total Cost: $300,000

Description of Technology and Application:

Previous studies of ambient levels of toxic air contaminants, such as the MATES II study, have found that diesel exhaust is the major contributor to health risk from air toxics. Analyses of diesel particulate matter in ambient samples has 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 is collecting particulate samples at ten locations in the South Coast Air Basin. Analysis of particulate bound organic compounds will be 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 may be 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 can be used to determine contributing sources.

The measurements 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:

As part of the proposed amendments to Rule 1110.2 "Emissions from Gaseous and Liquid-Fueled Internal Combustion Engines," staff is considering requiring additional monitoring, testing, recordkeeping, and reporting to improve compliance with the rule. 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 permitted on the basis of a single demonstration or periodic demonstrations of NO_x and CO emissions meeting SCAQMD rule requirements or a RECLAIM concentration limit. However, emission spot checks, for example SCAQMD unannounced tests on engines and boilers, have found that in many cases NO_x 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 O2 sensor known as a wide-band O2 sensor, is another alternative that can be analyzed. A more technical approach might to deploy technology utilizing the O2 signature of a post-catalyst O2 sensor and additional control concepts being developed by manufacturers. Since an underlying problem has been that engine, catalyst, and AFRC manufacturers have developed systems independently, a system being co-developed to perform continuous diagnostics to assist operators in keeping rich-burn engines in compliance is possibly another alternative for demonstration.

Potential Air Quality Benefits:

The 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_x emissions and about 6 percent of total CO emissions. There has been a long-standing compliance problem with rich-burn IC engines in the basin and evidence indicates that many of these devices are operating with NO_x and/or CO emissions above levels required in their permits. Projects could potentially reduce a significant class of NO_x and CO emissions that are in excess of the assumptions in the AQMP and further enhance SCAQMD's ability to enforce full-time compliance. Compliance with CARB's 2007 emission standards for distributed generation systems would also be a benefit.

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_x technologies (burners and ICEs)
- Low-Btu gas technologies (e.g., digester, landfill, or diary gases)
- Alternative fuels and hydrogen blends
- Alternative diesel fuels (emulsified, gas-to-liquids, biodiesel with aftertreatment)
- Low-emission refinery flares
- Catalytic combustion
- Cost-effective fuel cell and fuel cell hybrid distributed generation
- Fumes-to-fuel technology to replace thermal oxidizers and capture VOC emissions for electricity generation

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 AQMD 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_x, CO, hydrocarbon, and PM emissions levels. Replacing these devices with cleaner and more reliable technologies or technology/fuel combinations can have dramatic reductions in all of these criteria pollutants. VOC emission reductions may also be achieved at larger stationary VOC sources to achieve the new federal ozone and PM2.5 standards.

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

Expected SCAQMD Cost: $500,000

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 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.

Outreach and Technology Transfer

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

Expected SCAQMD Cost: $500,000

Expected Total Cost: $500,000

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 -mission 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
- 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_x 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
Pending Appointment	U.S. Department of Transportation
Dr. Sigmund Gronich.	U.S. Department of Energy
Pending Appointment	Westway Terminals
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, 2007

Contract	Contractor	Project Title	Start Term	End Term	AQMD $	Project Total $
Incentive Programs-Alternative Fuels						
01151	Virco Manufacturing	Purchase 30 Electric Forklifts with 2 Battery Packs	11/26/01	12/31/07	$424,190	$424,190
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
01178	Calmet Services, Inc.	Repower 27 Waste Collection Trucks with CNG	09/19/01	06/30/07	343,000	1,323,000
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 Laoder	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						
01154	R.F. Dickson Company, Inc.	Cost-Share Installation of CNG Fueling Facility	08/04/01	12/31/07	180,000	180,000
02157	Clean Energy	Upgrade Existing CNG Fueling Stations	01/17/02	02/28/07	892,615	1,445,112
03098	Taormina Industries	Develop LNG-L/CNG Fueling Station	11/26/02	07/31/09	203,682	213,000
03099	Sanitation Districts of Los Angeles County	Purchase& Install LNG-L/CNG Fueling 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 Fueling System at La Metro Hauling District	06/26/03	06/30/08	850,000	400,000
03103	Waste Management Recycling and Disposal Services	Develop LNG-L/CNG Fueling Station	10/23/03	12/31/08	850,000	400,000
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 Fueling Station	03/26/04	08/31/09	140,000	725,000
05109	Orange County Sanitation Districts	Upgrade CNG Fueling 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 Fueling 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 Fueling System at Commercial Fueling Station in Temecula	11/04/05	12/31/10	$203,137	$833,333

Contract	Contractor	Project Title	Start Term	End Term	AQMD $	Project Total $
Infrastructure and Deployment (cont'd)						
06000	Gas Equipment Systems, Inc.	Purchase & Install New CNG Fueling 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 Fueling Appliance	09/26/05	06/30/07	100,000	200,000
06018	American Honda Motor Co. Inc.	Incentive Buydown Program for CNG Home Fueling Appliance	11/02/05	06/30/07	300,000	600,000
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 Fueling Station at SoCalGas Santa Monica Facility	10/26/05	12/31/11	190,000	634,500
06030	Clean Energy	Purchase & Install CNG Fueling 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 Fueling 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 Fueling 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 Fueling 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 Fueling 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 Fueling Systems at City of San Fernando Public Works Dept. Yard	12/15/06	12/31/12	73,200	486,000
07003	Fontana Unified School District	Install CNG Infrastructure and Perform Garage Upgrades	09/05/06	12/31/07	$322,000	$450,000
07014	Gas Equipment Systems Inc.	Purchase & Install New CNG Fueling System at County of Los Angeles, Dept. of Beaches & Harbors Facility In Zuma Beach	12/15/06	12/31/12	150,000	525,000

Contract	Contractor	Project Title	Start Term	End Term	AQMD $	Project Total $
Infrastructure and Deployment (cont'd)						
07051	City of Pasadena	Purchase & Install New Public Access CNG Fueling Station	12/28/06	12/31/12	165,000	550,000
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	08/31/07	140,000	280,000
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 Model Years 2004 & 2005 Classes 7-8 Heavy-Duty Diesel and Natural Gas Fueled Trucks	12/13/06	08/15/07	240,000	240,000
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	08/31/07	260,000	1,920,435
04155	Engine Control Systems	Optimize & Demonstrate Oxidation Catalysts to Reduce Emissions from CNG-Fueled Heavy-Duty Vehicles	06/25/04	01/31/07	340,900	412,650
Electric/Hybrid Technologies						
99109	Toyota Motor Credit Corporation	Three-Year Lease of One RAV4 Electric Vehicle	04/04/09	02/01/07	23,154	23,154
04019	University of California, Davis	Optimize & Demonstrate Plug-In Hybrid Electric Vehicles	04/27/04	01/31/07	150,000	458,000
04032	Electric Power Research Institute	Develop, Demonstrate & Evaluate Plug-In Hybrid-Electric Vans in Fleet Use	04/27/04	01/31/07	475,000	1,525,000
05259	AC Propulsion Inc.	Upgrade & Evaluate a Plug-In Hybrid Electric Sedan with Lithium Polymer Batteries	07/25/05	07/24/07	25,300	53,000
05260	EnergyCS	Conversion of Light-Duty Vehicle to Plug-In Hybrid Vehicles	09/09/05	09/08/07	130,000	539,000
06182	ISE Research Corporation	Develop & Demonstrate a Natural Gas Hybrid-Electric Transit Bus	08/25/06	08/31/08	300,000	1,050,000
Engine Technologies						
05067	Cummins Inc.	Emission Control System in Low-Sulfur Diesel-Fueled Heavy-Duty Engines	03/09/05	07/08/07	$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	02/28/07	300,000	750,000
05244	Cummins Westport, Inc.	Develop, Demonstrate & Certify Heavy-Duty Natural Gas Engine to Meet 2010 Emission Standards	08/26/05	07/31/07	1,390,000	1,390,000

Contract	Contractor	Project Title	Start Term	End Term	AQMD $	Project Total $
Engine Technologies (cont'd)						
06033	John Deere Power Systems	Develop & Certify a Medium- and Heavy-Duty Natural Gas Engine	03/15/06	04/30/07	695,400	5,820,749
06068	Baytech Corporation	Develop & Demonstrate On-Board Diagnostic Systems for Natural Gas Vehicles	01/20/06	01/30/07	319,615	774,896
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	04/02/07	400,000	855,710
04111	Stuart Energy	Maintenance & Data Management for the AQMD 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
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	06/20/11	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 AQMD in Diamond Bar	02/04/05	06/04/07	240,000	1,240,000
04126	American Honda Motor Company	Lease of One Additional Honda Fuel Cell Electric Vehicle	06/22/04	07/23/07	22,733	22,733
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	03/31/07	257,500	572,604
Health Impacts Studies						
05037	California Air Resources Board	Enhanced Exposure Assessment of Health Effects of PM	06/28/04	10/31/07	501,814	4,392,814
05172	Desert Research Institute	Organic Compound Analyses of Particulate Matter Samples Collected Under MATES III	08/13/05	01/31/07	399,995	399,995

Contract	Contractor	Project Title	Start Term	End Term	AQMD $	Project Total $
Stationary Clean Fuels Technology						
03292	Occidental College	Professional Wet Cleaning Technology Demonstration & Pilot Incentive Program	06/23/03	02/28/08	16,000	391,000
05207	SolSource Energy	Install an 80 kW Solar Panel System at AQMD Headquarters	06/06/05	06/05/11	360,000	693,000
06017	Gas Technology Institute	Field Demonstration of Advance Technology Boiler in South Coast District	03/15/06	12/15/07	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	07/18/07	90,000	300,000
Outreach and Technology Transfer						
97110	Burke, Andrew F.	Review & Assessment of Technical Proposals Regarding ATTB Ultracapacitor System	06/04/97	08/31/07	15,000	15,000
97113	JME Inc.	Review & Assessment of Technical Proposals Regarding ATTB Ultracapacitor System	05/08/97	08/31/07	15,000	15,000
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	02/28/07	250,000	250,000
02295	Synchroenergies Inc.	Technical Assistance on Lubricants, Fuels, Combustion, Alternative Energy Sources, & High Performance Fluid Technologies	05/23/02	06/30/07	25,000	25,000
02308	Sperry Capital, Inc.	Evaluate Financial Stability of Potential Contractors	06/25/02	12/31/07	20,000	20,000
02311	Cole, Jerald A.	Technical Assistance for Development, Outreach, & Commercialization of H2 Infrastructure & Reforming Technology	08/09/02	06/30/07	30,000	30,000
02333	University of California, Riverside	Technical Assistance on Clean Fuels, Hydrogen, Fuel Cell & Natural Gas Technologies	11/01/02	06/30/07	$30,000	$30,000
02335	Neil C. Otto	Technical Assistance on Fuel Cell Technology	08/09/02	06/30/07	30,000	30,000
04049	Engine, Fuel & Emissions Engineering Inc.	Technical Assistance for Alternative Fuels Engine Technology	11/21/03	12/31/07	60,000	60,000
04053	Marathon Technical Services	Technical Assistance for Alternative Fuels Infrastructure	11/21/03	12/31/07	40,000	40,000
04097	Calstart	Ongoing Operation & Improved Functionality of Clean Car Maps Internet Website	06/15/04	01/31/07	110,000	355,000

Contract	Contractor	Project Title	Start Term	End Term	AQMD $	Project Total $
Outreach and Technology Transfer (cont'd)						
04123	Gladstein, Neandross & Associates LLC	Demonstrate Low-Emission, Alternative Fuel Heavy-Duty Vehicles within SCAB & Public Awareness Program	06/04/04	07/23/07	125,000	615,000
04146	Tom Gross	Technical Assistance for Hydrogen & Fuel Cell Technologies	06/23/04	05/31/07	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	07/06/07	401,400	2,213,274
05101	Joseph Calhoun	Technical Assistance for Development, Outreach & Commercialization of Advanced Low-Emission Vehicle Technologies	01/07/05	01/31/07	40,000	40,000
05120	Clean Fuel Connection, Inc.	Technical Assistance for Technology Incentive Programs to Evaluate Proposals for Compliance	04/01/05	03/31/07	130,000	130,000
05121	Sullivan, Cindy	Development, Analysis & Technology Implementation of Incentive Programs	03/14/05	03/31/07	75,000	75,000
05123	TIAX LLC	Development, Outreach & Commercialization of Low-Emission and Alternative Fuels	03/14/05	03/31/07	90,000	90,000
05125	Breakthrough Technologies Institute	Technical Assistance for Development, Outreach & Commercialization of Fuel Cells and Coordination with Federal Agencies	03/05/05	03/31/07	40,000	40,000
05126	St. Croix Research	Development, Outreach & Commercialization of LNG, CNG and Hydrogen Fuels	03/15/05	03/31/07	25,000	25,000
05127	Protium Energy Technologies	Development, Outreach & Commercialization of Hydrogen and Fuel Cell Technologies	03/14/05	03/31/07	40,000	40,000
05128	Mid-Atlantic Research Institute LLC	Development, Outreach & Commercialization of Advanced Heavy-Duty and Off-Road Technologies	08/08/05	03/31/07	40,000	40,000
05171	James Hazelton	Technical Assistance on AB 1222 Advisory Group	04/08/05	03/31/07	$45,000	$45,000
06109	Burnett & Burnette	Update & Expand School Bus Inventory in Basin	04/13/06	04/12/07	50,000	50,000
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	75,000	75,000
06173	Maria Robles	Administrative Assistance Services Related to Organization of International Conferences on Asthma and Port Emissions Control Technologies	05/12/06	08/31/07	125,000	125,000

Contract	Contractor	Project Title	Start Term	End Term	AQMD $	Project Total $
Outreach and Technology Transfer (cont'd)						
06211	Gladstein, Neandross & Associates LLG (GNA)	Co-Host the 3rd Faster Freight, Cleaner Air 2007 Conference	06/21/06	09/30/07	25,000	25,000
06217	Electric Power Research Institute	Technical Assistance for AQMD Plug-In Hybrid Electric Vehicle Forum & Roundtable	06/23/06	11/30/06	20,000	20,000
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	09/21/07	2,901	2,901
07059	Dowling Associates, Inc.	Technical Assistance Related to Air Quality Impacts of Regional Goods	12/19/06	11/30/08	58,000	58,000
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
07061	Westart-Calstart	Cosponsor 7th Annual Clean Heavy-Duty Vehicle Conference & 2nd Annual HICE Symposium	11/05/06	08/31/07	25,000	50,000
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

APPENDIX C

Final Reports for 2006

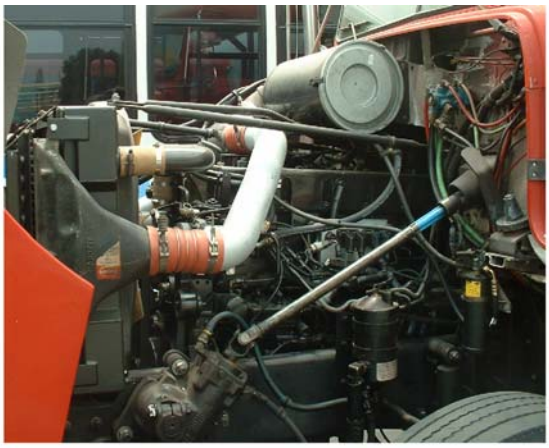
AQMD Contract #02293 **June 2006**

Develop & Demonstrate Fischer-Tropsch Fueled Heavy-Duty Vehicles with Control Technologies for Reduced Diesel Exhaust Emissions

Contractor
Automotive Testing Laboratories, Inc.
Cleaire
Cummins Engine Co.
Ralphs Grocery
Ricardo
Shell Global Solutions, US

Cosponsors
National Renewable Energy Laboratory
California Energy Commission

Project Officer
Adewale Oshinuga



Background

Gas-to-liquid (GTL) is an alternative fuel with several desirable properties that allow it to produce lower emissions than conventional fuels when burned in diesel engines. Interest in alternative fuels has increased due to their potential for burning cleaner and replacing imports of foreign oil. Recent studies of GTL fuel have shown promise in both areas. GTL fuel has much better ignition characteristics than diesel fuel, and near-zero Sulfur content. This research evaluated emission reductions from an integrated vehicle, engine and aftertreatment system that was designed to take advantage of the unique properties of GTL fuel.

Project Objective

The primary objective of this project was to meet the 2007 standards by integrating the GTL fuel with the engine modifications and emission control system. A secondary goal was to evaluate the technologies on an existing vehicle.

Status

The project was completed in October of 2005. The Final Report was submitted in April 2006.

Results

The goal of the project was to meet the 2007 emission standards through the integration of the GTL fuel, engine modifications and emission control system. Emission limits were focused on NOx and PM at 1.2 and 0.01 g/bhp-hr, respectively. In addition, NO2 was limited to 0.4, THC 1.3 and CO 15.5g/bhp-hr. Testing was conducted in an iterative process to determine the emission reductions attributable to each technology, starting with the fuel, progressing to the engine modifications and finally with the emission control system installed as shown in the following table.

Test Condition	NO_x	THC	PM	BSFC	CO	NO_2
	(all emissions in g/bhp-hr)					
Baseline	2.08	0.33	0.125	196.5	0.86	n/a
GTL Fuel	1.96	0.22	0.102	191.8	0.63	n/a
Eng Mods	1.56	0.18	0.122	197.0	0.91	0.21
Emis Cntrl	1.17	0.04	0.005	205.2	0.06	0.28
Target	1.2	1.3	0.01	n/a	15.5	0.4

The combined technologies successfully met all emission reduction goals with only a 4% increase in fuel consumption.

Test protocol followed the US EPA engine dynamometer test for heavy-duty engines. This Federal Test Procedure, or FTP, was used to evaluate progress toward the limits set for emissions, while a steady state test was used for development and refinement of the technologies.

Upon achieving the emission reduction targets, the modified engines and emission control systems were installed in delivery trucks operating in Southern California. These trucks were fueled exclusively with the GTL fuel stored in a temporary tank at the distribution facility. A maximum delivery route of 500 miles was established to preclude the necessity of offsite fueling. The technologies were able to meet the delivery fleet requirements, and driver feedback was overwhelmingly positive.

Benefits

The diesel engine emission reduction potential of GTL fuel has been proven. The 2007 engine certification standards were achieved with the GTL fuel and the technologies it enables. For the 2002 Cummins ISM engines used in this project, emission reductions of 95% for CO and PM, nearly 90% for THC and 40% for NOx were demonstrated, with only a 4% reduction in fuel economy. The use of GTL fuel would also reduce the nation's petroleum imports. GTL fuel is a direct and immediate replacement for diesel fuel. No diesel engine modifications are required for the switch to GTL fuel, however engine modifications permit the full realization of the fuel's emission reduction potential. The emission reduction and imported petroleum displacement benefits of GTL fuel should be modeled using various market penetration scenarios.

Project Costs

There were three deviations from budgeted contract costs. Two of these resulted from problems associated with integrating the modified engines into trucks that weren't designed for that engine. Several repair actions on both engine installations were required to resolve the problems. The time spent resolving unanticipated problems resulted in additional months of rent on the temporary GTL fuel storage tank. The repair and tank rent expenses resulted in a 2% increase from the contract budget.

Commercialization and Applications

The GTL fuel was shown to be a viable alternative to diesel fuel in existing and future engines. Production capacity was not determined in this project; therefore petroleum displacement cannot be quantified.

A heavy-duty vehicle manufacturer should be included in future research on GTL fuel to assist in the integration of the engine and emission control system into the vehicle. Also, models should be developed to assess the impact on the emissions inventory from various emission reduction and market penetration scenarios.

AQMD Contract #03467 **April 2006**

Develop & Demonstrate Aftertreatment Technology for PM & Hydrocarbon Emissions Control of CNG Fueled Heavy Duty Engines

Contractor
Westport Innovations Inc.

Cosponsors
NREL
Sempra Utilities

Project Officer
Adewale Oshinuga

Background

Over recent years, the physical and chemical characteristics of particle emissions arising from internal combustion engines have become an important area of research for those investigating advanced engine and aftertreatment technologies. Work has focused mainly on the particles emitted by diesel engines and advanced technologies to reduce diesel engine particulate emissions. Diesel Particulate Filters (DPFs) are one such technology. Some studies have also investigated emissions arising from Spark Ignited (SI) engines (including heavy duty natural gas fueled engines), and have compared them to DPF equipped light and heavy duty diesel engines.

Until recently, no studies have been published illustrating the direct effect of aftertreatment systems often fitted to spark ignited engines. Thus, the detailed effect of such systems on particle emissions is not well understood. By contrast many studies have investigated, in detail, the effect that DPFs have on diesel engine particulate emissions.

This program offers results to compare the impact that the oxidation catalyst and a specially selected wall flow particulate filter has on the physical and chemical characteristics of the particle emissions of the CWI C Gas Plus engine. In addition the impact of the lubricating oil condition on emissions will be assessed.

Project Objective

This program targets the development and optimization of catalyzed particulate filters (PF) to further reduce particulate matter and hydrocarbon emissions by at least 60 percent without increasing NOx, CO, and toxic pollutants emissions from CNG-fueled heavy-duty engines. In addition this project investigates the impact of lubricants on emissions from CNG engines, and assesses emission-reduction potential, performance, and reliability of the catalyzed particulate filters during a six-month in-use demonstration program.

Technology Description

The best available current technology to reduce particulate emissions from diesel engines is the particulate filter. Particulate filters are devices placed into the engine exhaust stream designed to force the exhaust gas from the engine to flow through porous structures within the particulate filter. The porosity of the filter walls and washcoat are designed to have a high trapping efficiency over a wide particle size range. The trapped particulate matter is either continuously oxidized or forced to oxidize periodically. Preferably, continuous oxidation takes place. To achieve continuous oxidation, the catalyst temperature must be above the balance point temperature. The balance point temperature is the temperature at which the rates of soot

oxidation and accumulation balance[1]. Thus, it is desirable to have a filter with a low balance point temperature. Lowering the balance point temperature is typically achieved using two related methods: (a) introducing a precious metal catalyst (either directly in the washcoat or with the diesel fuel); and (b) using highly reactive NO2 to increase the reaction rate of the trapped carbon. Increased concentrations of NO2 over the filter are achieved by placing an oxidation catalyst upstream of the filter. The upstream oxidation catalyst oxidizes the NO to create the NO2[2]. There is, of course, a cost-performance trade-off in that lower balance point temperatures can be achieved by increasing the precious metal content. The best performance (i.e., lowest balance point temperatures at comparable cost) has been demonstrated using a combination of upstream oxidation catalyst with some precious metal loading on the PF itself.

The vast majority of PF work has focused on diesel engines (for obvious reasons). The use of a PF in CNG SI applications introduces new considerations. For example, the composition of the particulate matter is expected to be significantly different. For diesel applications, the particulate matter consists of volatiles (≈20-40%), carbon, ash from the lube oil and SO4. The diesel PF is designed to oxidize the volatiles and carbon, but collects the ash continuously. The diesel fuel sulphur content must be severely restricted such that the SO4 particulate is not produced in prodigious quantities through oxidation reactions over the precious metal catalyst. For comparison, in CNG applications, the majority of the particulate matter consists of volatile organics and ash (fuel sulphur levels are typically very low). Little carbon is expected as the engine is run in a lean burn combustion mode. The implication is that the wall flow filter may simply serve to trap the ash; the volatiles can be oxidized using a standard flow through oxidation catalyst.

Status

This project was completed on 12th April 2006 with the submission of the final report to SCAQMD. The final report is on file with complete technical details of the project.

Results

There were two elements to this project; the first was to establish the effect of engine lubrication oil age on exhaust particulate emissions for CNG engines, the second was to investigate the effect of fitting a PF to an existing CNG Engine.

The investigation into the effects of the engine lubrication oil age showed that oil age does have a distinct effect on engine exhaust emissions. Some of the main trends are:

- On a particulate mass basis (WVU measurements), there is no statistical difference in mass emissions between the differing ages of engine oil.
- The Scanning Mobility Particle Sizer (SMPS) size distribution results showed, for the new oil, production of numbers of very small particles, with no significant production of particles larger than 30nm. This is indicative of volatile burn off. For the mid-life oil the large nucleation mode is absent, suggesting that volatiles are no longer present.
- Carbonyls emitted in quantifiable emissions rates were formaldehyde, acetaldehyde, propionaldehyde, and benzaldehyde. These emission rates were low (<0.1 g/kg fuel), but increased with age of oil.
- Greater differences in VOC emission composition were seen due to age of oil than due to the presence of not of the particulate filter.
- Propene emission rates increased in Idle tests with the age of oil.
- Hopanes and steranes are present in petroleum based engine lube oils and can be used as an indictor of emissions of lubricating oil (Schauer et al., 1999). In general, hopanes had higher emission rates in QCBD tests, and midlife and end-of-life oil had higher emissions.

Engine exhaust emissions are positively affected by the addition of a Particulate Filter (PF). Some of the main trends are:

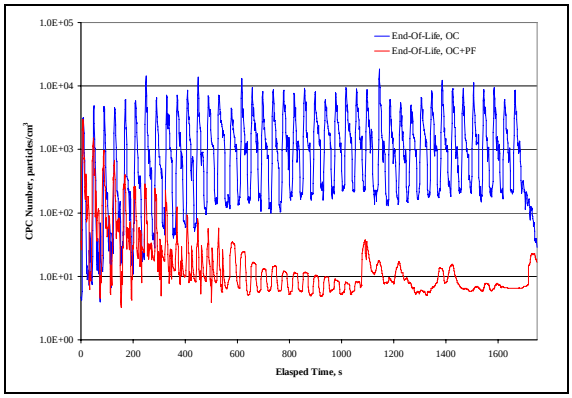
- The addition of the PF does not produce a statistically significant change in PM mass emissions. The particulate mass emissions measurement techniques used could not distinguish between OC only and OC + PF cases.

[1] The balance point temperature, of course, depends on engine out particulate emissions as well as the reaction kinetics.

[2] Under typical exhaust gas composition and pressures, thermodynamic equilibrium favours NO2 over NO at temperatures < ≈300C

In many cases and under many conditions, particle number concentrations were not detectable above background.

- The addition of a particulate filter is effective at removing start-up spikes in particle number concentration.
- By adding the particulate filter the size distribution is unchanged but the overall number is reduced.



Benefits

Application of a particulate filter has not reduced the PM_{10} but has been shown to reduce the ultrafine particle emissions from a CNG fueled engine.

Project Costs

AQMD's funding for this project totaled $480,000 with co-funding from Southern California Gas Company ($100,000) and NREL ($100,000).

Westports costs for non-labour items totaled approximately $180,000, with labour running at approximately $170,000.

The University of Wisconsin (subcontractor on this contract) was paid $149,816 for services provided. The University of Minnesota (subcontractor on this contract) was paid $211,668 for services provided.

Commercialization and Applications

This project has shown that particulate filter technology can be applied to Natural Gas engines with positive results.

AQMD Contract #05195 **July 2006**

Provide Transportable Emissions Testing of CNG-Fueled Heavy-Duty Engines

Contractor
West Virginia University (WVU)

Co-Sponsors
National Renewable Energy Laboratory

Project Officer
Adewale Oshinuga

The 2007 EPA emission standards for heavy-duty engines are aggressive, and manufacturers are evaluating numerous types of aftertreatment to be used to assist them in meeting these standards for their diesel vehicles. The development of these aftertreatment devices for heavy-duty engines has sparked interest in the use of these devices on heavy-duty CNG vehicles. Cummins-Westport, The South Coast Air Quality Management District (AQMD) and National Renewable Energy Laboratory (NREL), worked together to develop, install, and evaluate oxidation catalysts and particulate filters on a heavy-duty CNG engine, and study the effect of lube oil aging on exhaust emissions. This included an evaluation of lube oil effects on emissions and aftertreatment effectiveness. This project took the evaluation one step further to evaluate the performance of both the lube oil and aftertreatment devices on heavy duty CNG vehicles, using a mobile chassis dynamometer in Southern California.

Project Objectives

The objective of this study was to investigate the effect of the addition of a catalyzed Particulate Filter (PF), as proposed by Cummins-Westport, on the emissions from a CNG-fueled Heavy-duty engine. The project also investigated the impact of lubricant age on emissions from CNG engines. In addition, WVU assessed the emissions reduction potential of the catalyzed particulate filters after a six-month in-use demonstration program.

Figure 1 Transit bus on WVU Transportable Heavy-duty Chassis Dynamometer

WVU provided the Transportable chassis dynamometer and the emissions measurement system for regulated emissions. WVU also provided assistance to Univ. of Wisconsin (responsible for chemical speciation), Univ. of Minnesota (responsible for aerosol concentration and size measurements), and Westport Innovations who were the project lead.

Technology Description

The 40-ft long transit bus (New Flyer C40LF), provided by Sunline Transit Agency, was powered by a lean-burn spark ignited (LBSI), turbocharged CWI C Gas Plus engine. The fuel was metered into the intake (fumigation), and the air-to-fuel (AFR) was controlled by an oxygen sensor in the exhaust stream. The engine was equipped with a drive-by-wire throttle. The engine was rated at 280 hp at 2400 rpm with a peak torque of 850 lb-ft at 1400 rpm. The engine was certified to the following emissions levels: US EPA 2004, EPA CFFV ULEV, and CARB Optional Low NOx (1.8 g/bhp-hr).

It was shown in the previous study (AQMD Contract#03109) that the composition of PM from CNG engines is significantly different to that from Diesel Engines. Particulate matter emissions from CNG engines are characterized by lower mass emissions, larger fraction of ash and volatile organic fraction, lower elemental carbon. In addition the LBSI engines have a higher NOx to carbon ratio,

and higher minimum exhaust temperature compared to diesel.

Status

The project is completed. The final report has been submitted

Experimental Setup

All the testing was done on WVU's transportable chassis dynamometer and the emissions characterization was done using a clean dilution tunnel built exclusively to test natural gas engines to reduce the effect of background contributions from previous deposits and avoid fuel crossover effects. The entire study was divided into two phases. During Phase I complete emissions analysis (regulated emissions, chemical speciation, and PM size characterization) of the exhaust was done for "baseline" configuration, and with combinations of lubricants and exhaust aftertreatment system. In Phase II, after a six-month in-field demonstration program conducted by CWI, only regulated emissions were measured. Tests were conducted over the CBD cycle and steady state modes of operation.

Results

As expected, the particulate filter (PF) yielded significantly lower levels of particulate matter distance-specific (g/mile) emissions.

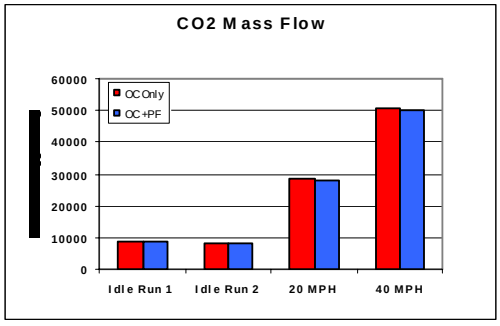


Figure 2 Mass flow rate of carbon dioxide emissions.

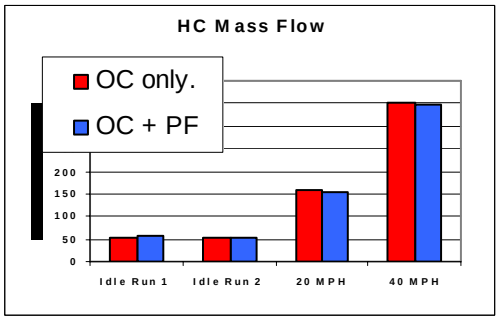


Figure 3 Mass flow rate of total HC missions

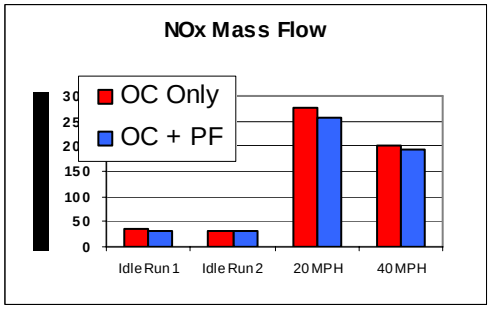


Figure 4 Mass flow rate of NOx emissions

Of particular interest was the fact that the PF did not adversely affect gaseous emissions.

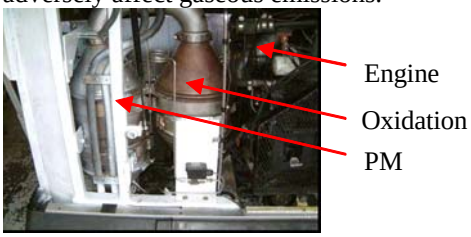


Figure 5 Exhaust after treatment system installed on the engine

Benefits

This study has shown that natural gas fueled heavy-duty engines can yield significantly lower emissions when they are retrofitted with a PF and an oxidation catalyst.

Project Costs

The project was completed with funds allocated for the study. No addition funds were requested.

Commercialization and Applications

The engine manufacturer, Cummins Westport was the lead on the project. It is expected that the manufacturer will provide the direction for commercialization and application of the technology.

AQMD Contract #00051 **February 2006**

Develop & Demonstrate an Electric School Bus

Contractor
Santa Barbara Electric Bus Works, Inc.

Cosponsors
US Department of Transportation Advanced Vehicle Program (Calstart), Bus Works, Los Angeles Department of Water and Power, South Coast Air Quality Management District, Sacramento Municipal Utility District

Project Officer
Lisa Mirisola

Background
Battery-electric power has been identified as having the greatest potential to reduce the emissions attendant to bus operation. Electric buses are also more energy efficient than diesel buses, and because electric-power generation utilized to recharge the batteries is not generally reliant on petroleum fuels, the use of such buses supports a reduction in the national dependency on foreign oil. The recharging of electric buses during off-peak hours also serves to maximize utilization of existing power-generation facilities.

Promising demonstrations of battery-electric technology in school buses were terminated when conventional batteries failed to achieve reasonable longevity or reliability during the 1990s. The most significant obstacles to the widespread adoption of battery-electric school buses were their relatively limited range, perceptions of poor reliability, and relatively high life-cycle costs.

To address these obstacles the Santa Barbara Electric Bus Works developed a medium- and heavy-duty advanced battery electric propulsion system, and converted a Blue Bird TCEV 2000 electric school bus from an unworkable lead-acid battery-electric propulsion system to the advanced sodium-nickel chloride battery-electric propulsion system.

Project Objectives
The project was designed to evaluate the drive system in daily student-transportation service for energy consumption, performance, suitability and reliability.

Technology Description
The ZEBRA sodium-nickel chloride battery technology was chosen for the project application as it had considerable technical merit when compared with the other candidate technologies. Most notable were its reasonable acquisition cost, high gravimetric and volumetric energy densities insensitivity to ambient temperature extremes, and low additional-component count minimizing technical risk in the development effort.

A reiterative design and design-review process examined potential hazards in normal and extraordinary maintenance and operational situations as well as the crashworthiness of the school bus. The sodium-nickel chloride batteries and their battery management system communicate with a stock high-power electric-drive system and achieve new levels of vehicle performance and efficiency using other stock components. The system also uses the drive inverters for battery charging.

Status
Inconsistencies between the vehicle's prototype status and the LA Unified School District's management practices prevented its evaluation there and the bus was moved to Napa for evaluation by the Napa Valley Unified School District, an experienced alternative-fuel user. The electric bus entered service at Napa during the second quarter of 2004. The bus was assigned to regularly scheduled pupil-transportation missions. The bus was operated by one driver on two runs per day, one in the morning and one in the afternoon. The two runs

were each approximately 34 miles long and were each completed in a little over one and one-half hours. Occasionally the bus was utilized for field trips.

The demonstration/evaluation project was completed in July 2005. The final report is on file with complete technical details of the project.

Results

Vehicle performance is comparable to conventionally powered school buses of similar size. Reliability of the bus has been better than that of any other electric school bus yet placed in service. All issues preventing regular dispatch of the bus have been corrected as encountered and may be largely attributed to its prototype status. A number of these problems were related to the conversion of an existing (used) bus for the prototyping effort and would likely not be encountered in a production vehicle. Maintenance on the prototype bus is simpler than on a conventionally-powered bus. There is no regularly scheduled powertrain maintenance other than inspection to verify the integrity of cabling and the cooling system.

The normal duty cycle of the bus yields an average speed of less than 20 mph and about 25% stationary time. Speeds to 45-55 mph are achieved for short distances on the bus' routes. Normally encountered road gradients range from ± 1-6% and occasional hills with ±8-12% gradients are encountered in the daily runs. Top speed is 62 mph and gradability is 15% at over 15 mph. The bus has exhibited comfortable margins of both power and energy.

Grid energy consumption in service averaged about 1.28 kWh/mile. Traction energy consumption averages 1.44 kWh/mi for driving and accelerating, and regenerative braking returns about 0.36 kWh/mile, giving a net energy consumption of 1.09 kWh per mile. Battery energy efficiency during operation averaged 84%.

Regenerative braking energy amounts to 25% of the traction energy expended and results in a range extension of almost 22%. Unrecharged range of the bus is from 60 to 70 miles depending on driver skills, average speeds and gradients, and passenger loads.

Two of the batteries were experiencing problems at the end of the evaluation period. The problems resulted from battery inactivity during the two-year stay at Los Angeles Unified School District but were corrected by the manufacturer. The bus continues in service with the Napa Valley Unified School District and has completed more than 450 operational runs. It is now dispatched on two daily runs of approximately 50 miles each.

Benefits

The pupil-transportation mission is a nearly ideal scenario for deployment of battery-electric vehicles. Centralized maintenance, close supervision of highly trained drivers, and a number of ideal routes all contributed to the success of this demonstration project. Total regulated emissions are approximately 9% of a 1998 diesel with catalytic converter and local NOx reductions of 94% or 660 pounds per year are realized on an 18,900-mile duty cycle.

Replacement of 3,000 pre-2000 30-foot diesel school buses in the South Coast Air Basin (estimated 100% market penetration) would result in an annual NOx reduction well in excess of 1,000 tons. Incremental costs in excess of $18,000 per ton of avoided NOx emissions are foreseen but total project cost is prohibitive. No additional adverse environmental impacts are likely.

Project Costs

A total of $717,130 was spent on this project with funding provided by the following sponsors: USDOT/Calstart ($322,148), Bus Works ($138,006), LADWP ($106,976), SCAQMD ($100,000), and SMUD ($50,000). Although project costs were significantly higher than the originally projected $400,000 because of modified work scope and project delays, the additional costs were fully borne by USDOT, Bus Works, and SMUD, with no additional funding required from SCAQMD.

Commercialization and Applications

Commercialization of the technology for school-bus use is not anticipated because the substantially higher vehicle cost is beyond the reach of most school transportation budgets. However, the technology is appropriate for replacement of 40%-60% of diesel and CNG transit bus fleets of 30-foot class transit buses. The technology is now ready for commercial use pending integration into specific platforms.

AQMD Contract #04143 **July 2006**

Public EV Charging Equipment and Signage Replacement

Contractor
Clean Fuel Connection, Inc.

Cosponsors
None

Project Officers
Lisa Mirisola

Background

In recent years, battery electric vehicles (EV) by General Motors, Honda, Toyota, Ford, Daimler-Chrylser, and Nissan have been introduced using several different charging systems as technology and charging standards evolved. Large paddle inductive (LPI) chargers compatible with the 1997 and 1999 GM EV1 and 1999 Toyota Rav4 EV and Nissan Altra EV, were not compatible with the needs of 2001 and later Toyota Rav4 EVs and Nissan Altra EVs that use small paddle inductive (SPI) chargers.

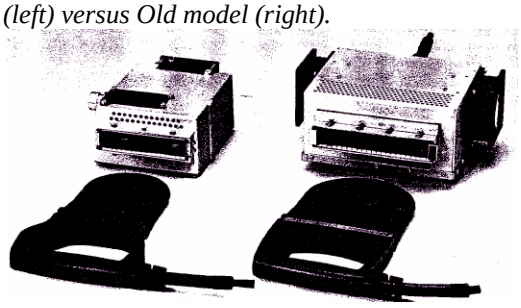
Project Objective

There are about 300 public charging stations with LPI chargers and no SPI chargers within AQMD. 25 SPI chargers were installed at high priority sites using selection criteria, including high visibility destination, EV driver input regarding frequency of and potential for site use, maintenance of a distributed network of EV charging especially along major transportation corridors, previously MSRC funding, replacement of out-of-warranty LPI chargers, and site cooperation.

Technology Description

Toyota and General Motors joint development for inductive technology has engineered a new inductive EV charging system with a coupler (paddle and charge port) having its size and weight significantly reduced-substantially by half as compared with the prior model. This SPI model, named the Gen III Charger by TAL, was the model used at all selected locations. It serves to satisfy the demand of small port EVs, while continuing to support large port EVs with a simple adapter.

Coupler (Paddle and Charge Port): New model (left) versus Old model (right).



Status

The project duration was from June 2004 and completed in July 2006. All retrofits at 25 selected locations have been completed.

Results

Clean Fuel Connection, Inc. (CFCI) worked with the AQMD and stakeholders including EV drivers, automobile manufacturers, charger manufacturers, charging equipment distributors, local electric utilities, public charging site providers, and other government agencies to prioritize charger replacement. Upon acceptance of a prioritized list by AMD, CFCI arranged for charger installation at agreed locations.

The results of site location, by county, are as follows:

Los Angeles County	56%
Orange County	24%
Riverside County	12%
San Bernardino County	8%

A detailed list and an area map of all sites have been submitted.

Benefits

The benefit of this project was to enable SPI charging at as many high priority locations as possible, without impacting the availability of LPI charging. By installing no more than two SPI chargers per site, CFCI was able to maximize the SPI charging location network. This resulted in shorter distances in between public EV charging stations and a greater support and use of EVs.

Project Costs

The AQMD contributed $100,000 for this project. The cost to replace one pedestal mounted LPI charger with a pedestal mounted SPI charger including labor is estimated at $3,500-4,000. Cost variation includes whether the charger was wall mounted, if site rework/rewiring is required to meet current codes and warranty requirements, and whether replacement signage is required. This project provided funds to install 25 SPI chargers. A cap of $4,000 per charger was set so that cost-effectiveness was one of the criteria used to prioritize charger replacement. Replacement of missing, broken, or defaced signs were considered on a case-by-case basis to encourage driver access.

AQMD Contract #05110 **June 2006**

Develop Heavy, Heavy-Duty Natural Gas Engine for Class 8 Trucks

Contractor

Westport Research Inc.

Cosponsors

National Renewable Energy Laboratories

Project Officer

Naveen Berry

Background

There are no natural gas engines available in North America today with ratings above approximately 320hp. The market for Class 8 tractors typically requires engines with ratings above 400hp. Development of viable natural gas fuelled engines meeting the performance requirements for Class 8 tractors would extend the availability of alternative fuelled, clean engines into applications with typically the highest emissions of air contaminants and the highest consumption of petroleum based fuels.

Project Objective

The project objective was to advance the readiness of Westport's HPDI technology using LNG as a fuel for Class 8 tractor engines. The project targeted development of 400hp and 450hp heavy duty engine ratings based around a 15 liter Cummins ISX diesel engine platform. As well as technology development, the project scope called demonstration of production ready engines in a commercial fleet, and the development of initial low volume manufacturing capability to facilitate subsequent commercial availability of the technology, with engines certified at or below 1.2g/bhp-hr NOx and 0.1 g/bhp-hr for Particulate Matter (PM).

Technology Description

Westport's proprietary HPDI technology facilitates the use of natural gas as an engine fuel while retaining typical diesel engine combustion, power and torque. A unique and patented injector design delivers a small volume, approximately 6% by energy, of diesel as the ignition source, and high pressure natural gas directly to the engine combustion chamber. With the low emissions profile of natural gas, and the high efficiency of a diesel combustion cycle, the technology offers potential for combining high energy efficiency with low emissions. The technology differs from other natural gas engines through the absence of spark plugs, and the direct injection of both fuels. The combined effect is that HPDI is the only existing technology to match diesel performance and efficiency with natural gas.

The HPDI system extends beyond the fuel injection equipment, and is developed as a fully integrated system including electronics, LNG tanks and vehicle installation.

Status

The project is complete and the final report, dated July 10th 2006 is on file. During the 18 month project, certification testing of the HPDI system was completed in October 2005, with CARB Executive Order issued for the product in March 2006. Delivery of 3 demonstration HPDI systems to Norcal Waste Systems in San Francisco was completed in July 2006. The development engineering conducted extended fuel efficiency in a second trial fleet to within 2% of equivalent diesel trucks.

Challenges overcome during the project included the refinement of controls and fuel injection strategies to improve the performance of the

HPDI system and significant redesign of LNG pump and tank systems to reduce cost and improve reliability in preparation for production.

Through the advancements made during this project, the HPDI technology has been made commercially available for Class 8 truck applications in introductory volumes with customer deliveries expected for Q4 2006.

Results

The table below represents the key performance characteristics of the HPDI system as developed during the project:

	ISX HPDI
Rating 1	**400 hp @ 1800 rpm 1,450 lb-ft @ 1200 rpm**
Rating 2	**450 hp @ 1800 rpm 1,650 lb-ft @ 1200 rpm**
EPA Cert	**1.2g NOx, 0.02g PM**
Emission Control	**EGR + Oxicat**

Emissions targets were met for all pollutants except for PM, where the target was 0.01g/bhhr. The certification testing established engine performance at the target emissions levels, but errors in the calibration tables meant that over the required Deterioration testing the PM emissions increased to the levels in the table above. Revisions to the calibration tables have been developed for implementation in commercial engines.

Benefits

The NOx emissions represent an approximate 50% reduction compared to the equivalent model year diesel engine, and 80% for PM.
With an average of 94% of the fuel burned in the engine being natural gas, operation of a HPDI engine would result in a 94% reduction in the use of petroleum for every truck in use. The combination of high fuel efficiency and the low carbon signature of natural gas results in greenhouse gas reductions of approximately 18% to 20% compared to an equivalent model year diesel engine.

The deployment of a fleet of 100 HPDI trucks in the South Coast Air Basin, displacing model year 2006 diesel trucks, would result in a reduction of approximately 100 tons per year of NOx emissions and 2.2 tons per year of Particulate Matter and a reduction in consumption of approximately 1.5million gallons of diesel fuel annually. The SCAQMD, along with the local ports, are planning to develop a program to place such a fleet in service.

Project Costs

The total project costs were estimated at $5.653 million. AQMD sponsorship of the program was contracted at $1.935 million, with the balance funded by NREL and Westport.

The project ran to the budgeted cost schedule, and AQMD total funding was equal to the contracted amount of $1.935 million.

Commercialization and Applications

The technology has been developed to the point where it is being offered for commercial sale into California in Q4 2006. Applicable applications include refuse transfer trucks, container trucks operating at ports, regional goods haul, bulk haul and vocational fleets.

Future developments in the technology for prolonged commercial application include development of emissions control solutions beyond the 2007 and towards the 2010 EPA emissions standards. Vehicle integration and OEM availability is a key aspect of furthering the penetration of the technology into the market.

The initial commercial roll out of the HPDI technology is targeted for California, and in particular the South Coast Air Basin. Key target customers include fleets operating out of the Ports of Los Angeles and Long Beach in support their Clean Air Action Plan.

AQMD Contract #05161 **September 2006**

Develop & Certify Natural Gas-Powered Ford Vehicles

Contractor
BAF Technologies

Cosponsors
SCAQMD
NYSERDA
Clean Energy

Project Officer
Von Loveland

Background
In light of increasing populations, and vehicle-miles-driven, air quality continues to suffer. At the same time, the availability of on-road alternative fuelled options from OEMs has actually fallen. These issues set the stage for a project that would bring to market additional alt-fuel vehicles targeted towards high-mileage fleet operators. By increasing the availability and use of Compressed Natural Gas (CNG) vehicles, this project benefits from the many advantages of natural gas: CNG is a proven engine fuel technology; previous investments made to expand the infrastructure of CNG fuel stations; lower tailpipe emissions; and, increased usage of natural gas lessens U.S. dependence on foreign oil, at a time of increasing geopolitical tensions. Additionally, recent increases in the retail price of gasoline and diesel fuel have negatively impacted all drivers, fleet operators in particular, and the economy as a whole.

Project Objective
The primary objective of this project was to bring to the marketplace additional certified CNG vehicles in light of Ford's decision to terminate production and sale of natural gas vehicles in the U.S. This was to be accomplished by the introduction of a dedicated CNG CARB/EPA certified Crown Victoria for MY 2005 and 2006, and a dedicated CNG CARB/EPA certified 6.8L E-450 for MY 2005 and 2006. But, with the departure of TeleflexGFI as a subcontractor a modification of the original Statement of Work (SOW) was issued which dropped the requirement for the MY 2005 Crown Victoria.

Technology Description
For the MY 2005 and 2006 6.8L E-450, BAF selected to certify the CNG compuvalve system from TeleflexGFI. However, in pursuing a replacement for the factory Ford Crown Victoria it was determined the project would require development of an entirely new fuel injected system. The new system would be closely aligned to the factory Ford Crown Victoria, using the OEM Powertrain Control Module (PCM) to control the CNG fuel injectors and provide system diagnostics. This was accomplished by installation of an Injector Driver Module (IDM) between the PCM and the CNG injectors (required to amplify the current flow) and modifying the original PCM programming. Utilization of the OEM PCM also allowed BAF to achieve full OBD-II compliance.

Status
The project was completed in whole and the EPA/CARB certification documents for both the Crown Victoria and the 6.8L E-450 were attached to the Final Report submitted May 5, 2006.

A 2005 Ford 6.8L E-450 was used to design prototypes of the CNG tank system and other high-pressure hardware items. Testing was completed at Rousch Industries in Detroit and certification applications were filed with both EPA and CARB. For MY 2006, with no appreciable changes in the base vehicle from Ford and no changes to the TeleflexGFI

compuvalve system, the MY 2005 certification was a direct "carryover" for MY 2006.

As stated above, though modified, the original SOW required a MY 2005 CNG Crown Victoria. This was to be accomplished using a fuel-injected system manufactured by TeleflexGFI. However, after extended testing it became apparent that system could not achieve the targeted SULEV emission standard. At that point TeleflexGFI decided to end their participation in the development of the Crown Victoria system and BAF undertook the development of a new sequential fuel injection (SFI) system for MY 2006. Using the same CNG fuel rails and injectors from TeleflexGFI, BAF developed an IDM to allow the OEM PCM to control the injectors and new PCM software.

BAF was able to negotiate and purchase the remaining inventory of CNG tanks from both Ford and the original tank manufacturer, Pressed Steel Tanks, of Milwaukee, WI. Prototypes of the remaining high-pressure components and brackets were designed and test fit on the car before beginning the certification tests.

Emission testing of the system was performed at Prodrive Englehard in Wixom, MI. Initial tests results indicated the system had the ability to achieve the SULEV standard, though many more hours of development were needed. BAF labored from November 2005 until April 2006 to complete emission and OBD-II compliancy testing. Special thanks go to Ford Motor Company for their support of the project by allowing BAF to use aged catalytic converters to complete the Catalyst Monitor portion of the OBD-II test.

Results

Tables 1 and 2 below provide emission test results for both the CNG 6.8L V-10 engine and the CNG Crown Victoria. In both cases the test data clearly shows the certified emissions meet the targets set for this project. The CNG 6.8L engine was certified to the lowest available standard; the 2006 MY CNG Crown Victoria was certified to the stringent SULEV standard.

TABLE 1. *6.8L EMISSION TEST RESULTS*

Component	Test Data	EPA DF	EPA CERT	CARB DF	CARB CERT
THC	0.251	1.9	0.4769	1.75	0.4393
NMHC	0.031	2.2	0.0682	1.46	0.0453
CO	1.6284	1.6	2.6054	1.75	2.8497
NOx	0.3532	1.3	0.4592	1.58	0.5581
HCHO	0.000139	2.2	0.000306	1.75	0.000243
NOx+NMHC	0.384		0.527		0.603

TABLE 2. *CROWN VICTORIA EMISSION TEST RESULTS*

Pollutant	NMOG	CO	NOx	HCHO	HWYFET / NOx
Standard	0.01	1.00	0.02	4	0.026
120K Results	0.004	0.755	0.016	0.299	0.023

Benefits

Benefits of this project are primarily tied to lower tailpipe emissions. By comparison the SULEV CNG Crown Victoria emits 52% less CO and 70% less NOx than the OEM ULEV gasoline vehicle. The CNG 6.8L engine meets the lowest standard for NMHC+NOx. CNG vehicles also produce less CO2, which contributes to global warming. Beyond direct emission reductions this project has successfully brought to the marketplace two new options for fleet operators to purchase reliable natural gas vehicles, at a time of increasing demand on the world's diminishing supply of crude oil.

Project Costs

The cost share allocations are: BAF Technologies – $577,600.00; TeleflexGFI – $313,800.00; NYSERDA – $300,000.00; SCAQMD – $300,000.00; and Clean Energy – $50,000.00. Total costs of the project are unchanged. However, with the departure of TeleflexGFI from the development of the 2006 Crown Victoria, the contractor absorbed their portion of the costs.

Commercialization and Applications

This project funded two different CNG fuel system technologies: the TeleflexGFI compuvalve system used on the 2005 and 2006 6.8L E-450; and a new BAF sequential fuel injection (SFI) system developed for use on the 2006 Crown Victoria. Using both systems the contractor was able to successfully certify these models with both EPA and CARB. Total sales of MY 2005/2006 have exceeded 300 units. Going forward, BAF expects a significant increase in sales for MY 2007 as we have already begun work to carryover the 2006 Crown Victoria certification for MY 2007, and re-certify the 6.8L E-450 using the now-proven BAF SFI system.

Additional applications of this technology are being examined; in particular, the MY 2007 Ford E-350 and the F-150.

AQMD Contract #03198 **January 2006**

Develop & Demonstrate Electrolyzer-Based Hydrogen Fueling Station Near LAX

Contractor
Praxair

Cosponsors
U.S. Department of Energy
California Energy Commission

Project Officer
Gary Dixon

Background
Automobiles are a significant source of air pollution due to NO_x, CO, CO_2, and other pollutants emitted from the tailpipe. This is a particularly important problem in Southern California. Hydrogen-powered fuel cell vehicles emit no NO_x, CO, or CO_2 from the tailpipe. If these vehicles can become a reality, tailpipe emissions will decrease significantly. This station will help to demonstrate the current status of hydrogen-powered fuel cell vehicles and promote their continued development toward commercialization.

Project Objective
The Hydrogen Refueling Station is located at the Los Angles International Airport (LAX) at 7450 World Way West. It is capable of supplying the refueling needs of up to 5 light-duty passenger vehicles with high-purity hydrogen gas. The maximum system production is 24 kg/day (1 kg/hr). This hydrogen delivery system is fully compatible with proton exchange membrane fuel cell and hydrogen fueled internal combustion engine vehicles utilizing on-board storage of up to 5,000 psig. The system allows the fast fill of 5 kg of hydrogen per fill within a 5 minute period, or a slow fill at 0.25 kg H_2/min.

Technology Description
The hydrogen fueling station will supply the fueling needs for a small fleet of hydrogen fueled vehicles in Southern California. The station is comprised of four major components; an electrolysis system, an intensifier, a storage receiver, and a hydrogen dispenser. Hydrogen is produced in the electrolysis system by electrolytically splitting water into hydrogen and oxygen. The hydrogen is purified by removing trace oxygen from the saturated gas by passing the stream through a catalyst bed. Trace oxygen contained in the product hydrogen stream is reacted with hydrogen over a catalyst to form water before being removed in a molecular sieve dryer. The oxygen-free, dried hydrogen gas is discharged to the hydrogen intensifier. The purified hydrogen gas is compressed through a multiple-staged booster intensifier and stored in a cascade arranged receiver bank storage system. The hydrogen fueling of vehicles is controlled by the hydrogen dispenser, which is integrated closely with the station controller.

Status
The fueling station has been completed and is fully operational. Hydrogen production, compression, storage, and dispensing have been demonstrated in successful test fills of hydrogen-powered fuel cell vehicles completed on May 27, 2005 and July 21, 2005. The final report providing the technical details of the project was submitted in January 2006.

The utilization of the station has been limited by the availability of hydrogen-powered vehicles.

LAX has recently completed negotiations with DaimlerChrysler to obtain hydrogen-powered vehicles for use at the airport. Once these vehicles are operating at the airport, it is expected that station utilization will increase significantly. These vehicles are expected to be delivered in early 2006.

The other major problems encountered in the project caused delays and cost overruns, but were not fatal. These problems were overcome with significant negotiating effort to arrive at a solution that mutually satisfied all participants.

Results

The station produces no emissions of NO_x, CO, or CO_2. This is exactly what was expected. The amount of benefit attained is directly proportional to the number of vehicles. Because there have been fewer vehicles than originally anticipated, the benefit has not been as large as originally hoped at the start of the project. However, more vehicles are expected in the near future and it is possible that the anticipated benefit could eventually be realized because the station continues to be available. Fuel cell vehicles are also more efficient than conventional vehicles, so the total energy consumed per mile of driving will decrease as fuel cell vehicle use grows.

The main performance tradeoffs are related to the electrical power consumed by the station. The energy required to produce the hydrogen that will provide power to the zero-emission vehicles has to come from somewhere. If renewable resources are used to produce this power, such as wind power, tidal power, or hydroelectric power, the only emission tradeoff is that the power consumed was not available for another use. However, if the power is generated in another way, the emissions from the power generator must be considered. If this power is produced outside the South Coast Air Basin, the total emissions in the Basin will definitely decrease. However, if the power is produced inside the Basin, some of the emissions reduction from the tailpipe of the vehicles will merely be transferred from the tailpipe to another part of the Basin. Another possible consideration is that it will be much easier to sequester CO_2 from a single stationary source (large power plant) than from many mobile sources (vehicles).

Benefits

It is expected that the fueling station will provide hydrogen fuel to a small fleet of DaimlerChrysler fuel cell vehicles utilized by LAX personnel. There is the opportunity however, to provide additional fueling to other fleet vehicles in the South Coast Air Basin.

Hydrogen-powered fuel cell vehicles produce no NO_x, CO, or CO_2 emissions and are more efficient than gasoline-powered internal combustion engine vehicles. If their use becomes prevalent, tailpipe emissions, which are a significant component of NO_x and CO emissions, will substantially decrease. Depending on how the hydrogen is produced, total emissions, including global warming gases, can also be significantly reduced.

The eventual benefit of this technology will depend on the source of hydrogen, or if electrolysis is used, the source of electricity. The technology used here reduces air pollution without producing any water pollution, solid waste, global warming, or toxic emissions. However, there is a tradeoff that must be considered because the process does consume electricity, which most likely means increased power production and potentially increased emissions at the power generator.

Project Costs

The total project cost was $1,772,911. AQMD provided $351,000 toward the cost. The actual costs were higher than projected due to contract negotiations and permitting issues.

Commercialization and Applications

Commercialization of this technology depends on the availability of fuel cell vehicles. If there is a sufficient number of vehicles, codes and standards for refilling stations will be developed and stations will be built. Obviously, if all vehicles used hydrogen-powered fuel cells, the market and the potential emissions benefit would be enormous.

AQMD Contract #04012 **April 2006**

Install & Demonstrate Electrolyzer-Based Hydrogen Refueling Station in Diamond Bar

Contractor
Stuart Energy

Cosponsors
AQMD

Project Officer
Gary Dixon

Background

The AQMD is committed to improving air quality in the South Coast Air Basin throughout the implementation of zero-emission technology. Gensets employing internal combustion engines (ICEs) modified to run on hydrogen (rather than diesel or natural gas) represent one such technology.

Project Objective

The objective of this project is to demonstrate co-location of a hydrogen-based power production and hydrogen fueling station in a multi use H2 energy station. This is achieved by expanding the existing Hydrogen Fueling Station (refer to Project #04012) at the AQMD headquarters in Diamond Bar, CA to include a hydrogen genset.

It should be noted, however, that in this project the hydrogen genset will only be used as a local isolated power supply. The AQMD does not intend to feed power back into the grid and therefore, the genset supplied has no means of phase synchronization with the building's grid power supply.

Technology Description

In a genset, energy stored in the chemical bonds of the fuel is converted into mechanical work in the internal combustion engine, which in turn, is converted into electrical power by the alternator. A conventional engine is designed to run on diesel, LP or natural gas as fuel, and consequently, produces a variety of emissions as a by product of combustion. In comparison, a genset utilizing hydrogen as fuel has much lower emissions and potentially no dependence on fossil based fuel (depending on the method used to generate hydrogen).

To adapt a genset for hydrogen fuel, Stuart Energy (in conjunction with Ford Power Products and Generac) modified a standard natural gas-powered genset. This conversion primarily involves changes to the fuel delivery system and the timing of the combustion system, specifically: the addition of a turbocharger, hydrogen specific fuel injectors and spark plugs and tuning of the electronic engine control system for optimal performance with hydrogen.

It should be noted that electric power can also be produced from hydrogen using a fuel cell. However, at this size range of 125 kW, the H2 genset is substantially lower cost than a similar size fuel cell.

Figure 1: Genset installed at AQMD headquarters in Diamond Bar, CA.

Status

The existing Diamond Bar Hydrogen Fueling Station was designed with provisions for a genset, minimizing site installation. The genset equipment was tested at the contractor's facility

in February 2005, delivered to site in July 2005, and commissioned in August 2005.

A significant factor in the delayed delivery was due to time in obtaining permits from the Fire Marshall's office. For future projects Stuart Energy would recommend that, more time and technical resources be dedicated to this process.

More information is available in the Stuart Energy Commissioning report.

Results

The genset installed at Diamond Bar receives hydrogen from the existing gas control panel at pressure of <300 psi, and is initiated via an automatic transfer switch. Emission testing is planned for the genset installation, however at the time of this report, results were not yet available.

The testing has not been scheduled. We would like to provide the emissions test results in a follow up submission as soon as they are available.

Benefits

There are several benefits to hydrogen gensets. In comparison to standard diesel or natural gas gensets, emissions of hydrogen gensets are much lower. Lower emissions improve local air quality. Provided that the hydrogen is produced using 'clean' methods, these benefits do not come at the expense of other environmental considerations (solid waste, air pollution, water pollution).

Project Costs

The value of this contract was US $100,000. Originally, the funding of this contract was to be provided by the California Energy Commission (CEC), however due to lack of resources the CEC had to withdraw and the funding was provided by the Clean Fuels Fund.

Without an available source of hydrogen from the fueling station (refer to project #04012), cost of this project would escalate due to the need for a dedicated hydrogen supply (via a separate generator or tube-trailers) and storage system.

It should be noted that the costs associated with permitting delays and other project related costs were borne by Stuart.

Commercialization and Applications

H2-ICE gensets can be employed in standby or backup power applications, similar to today's commercial diesel generators. However, unlike diesel generators, H2-IcE gensets are near emission-free.

H2-ICE's have similar applications as fuel cells: in power generators and as vehicle engines.

While at the very early stages of commercial stations, Hydrogen gensets represent the promise of low-emission power for peak-shaving or back-up purposes at a fraction of the cost of fuel cells.

AQMD Contract #03269 **July 2006**

Develop, Demonstrate & Evaluate Truck Fuel Cell Auxiliary Power Unit

Contractor

University of
California, Davis

Cosponsors

Argonne National Laboratories

Project Officers

Dipankar Sarkar

Background

The contract has addressed and measured the diesel emissions from Trailer Refrigeration Units and we have also carried out a detailed demonstration of a Fuel Cell APU as a power source for the Trailer Refrigeration Unit. This is one of the first projects to quantify the emissions and working cycle of diesel driven TRUs. This information is needed for future regulation of this efficient and economic power source.

Project Objectives

Current TRUs need to be characterized so that they can be realistically regulated. The objective of this thesis is to show the current pollution characteristics of unregulated TRUs. In order to characterize the TRUs, four (or five if NO is considered separately form NOx) gases needed to be measured: NOx, CO2, CO, and O2. This allowed air-fuel ratios to be calculated using a carbon balance and O2 exiting the engine. Oxides of nitrogen and carbon monoxide were calculated in grams per hour and grams per kW-hour, both engine and cooling power measures.
The TRU emissions information gathered has two clear uses. The first use for TRU emissions data is as input for creating computer models of TRUs. The second way TRU emissions data can be used is as a foundation to create reasonable regulations on TRUs in the future. The second objective related to the support of Argonne National Laboratories was to demonstrate a Fuel Cell Powered TRU, and to reflect on the use of this power source in the future.

Technology Description

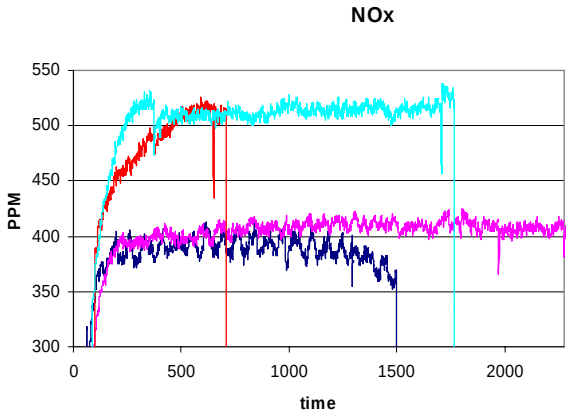
Since the emissions analyzer used to measure the pollution from TRUs was a laboratory quality analyzer, the values obtained were both accurate and precise. These accurate emissions measurements have gave us a good understanding of how TRU diesel engines perform, and a more complete characterization of TRUs. In order to characterize the whole TRU, the operating characteristics of the TRU was measured and documented.

Status

All of the goals of the project were accomplished with the exception of not using a solid oxide fuel cell. The UC Davis team was not able to procure a solid oxide fuel, however a PEM fuel cell was adapted to the project. With this fuel cell all project objectives were accomplished.

Results

It was found that NOx production is similar to other compression ignition power plants, in the range of 4.5 grams per kW hour for the Supra 744 and 5.0 grams per kW hour for the Extra XT. An analysis of the complete TRU system found that the system had higher parasitic loads and lower refrigeration efficiency than originally expected. Since the loads on the engines were found to be large and the refrigeration system was not an ideal vapor compression refrigeration cycle, the COP of the whole system was found to be between 1 and 1.5 for all the TRUs during pull down. The final value for grams of NOx per kW of cooling was determined to be about 3.6g/kW hour for the 744 in cold weather, 5.15 g/kW hour for the 744 in hot weather, 4.3 g/kW hour for the XT in cold weather, and 4.34 g/kW hour for the XT in hot weather. Real time NOx measurements in the field on working TRU diesel systems have been carried out, and typical data is shown in the figure below.



The UC Davis team has built and demonstrated a complete hybrid fuel cell system on a modern TRU system, see Figure below. The actual commercialization of the system is years away, however the system is feasible.

Benefits

Transport Refrigeration Unit, or TRU, is an example of a diesel emission source that will be regulated in the future. The TRU is used to provide refrigerated space during the transport of fruits, vegetables, meat, pharmaceuticals, beverages, and any other product that needs a temperature controlled environment while being transported. TRUs are used in all modes of transport, on rail cars, on ocean going shipping containers, over the road truck trailers and even on airplane Unit Load Devices. If the present diesel APU is to be replaced with a cleaner and more efficient system, it will have to be reliable and economical, however the benefits to society will be very significant.

Project Costs

There was a major problem with the project that was overcome by the extensive use of the facilities, faculty, and students of UC Davis. The problem was that the Chevron Corporation, which was a partner with UC Davis on the project, did not deliver on its promise of a five kilowatt Solid Oxide Fuel Cell. This major problem did not influence the emissions testing of conventional diesel powered TRUs, however it had a major influence on the demonstration of the Fuel Cell powered TRU. In order to complete the fuel cell part of the project the UC Davis team had to donate PEM fuel cells to the project and they had to build the majority of the power electronics used in the fuel cell powered TRU demonstration. As a result of this major revision UC Davis contributed a couple of years of Research Assistant time, as well as eight or nine months of faculty and research staff time. The end result was very satisfying since all of the general goals of the project were accomplished.

Commercialization

At the present time there has to be significant developments in Solid Oxide Fuel Cells and Battery systems in the power range for TRUs for hybrid fuel cell systems to be viable. However, the improvement in diesel engine systems may prove to be more rapid and reliable than other options. Therefore, there is hope on the horizon for more efficient and cleaner TRUs systems.

AQMD Contract #03287 **December 2006**

Develop & Demonstrate Integrated Autothermal Cyclic Reformer and PEM Fuel Cell

Contractor
California Air Resources Board (CARB)

Cosponsors
CEC
GE Global Research
CARB

Project Officer
Howard Lange

Background
Polymer electrolyte membrane (PEM) technology is the most suitable type of fuel cell for relatively small-scale distributed generation at residential or small commercial buildings. Since the fuel cell requires hydrogen as its fuel, the fuel cell must be equipped with a reformer to convert natural gas to hydrogen. A major obstacle for commercialization of PEM fuel cell power units has been that conventional reformer technology does not scale down well, and small-scale reformers have relatively high capital costs. GE Global Research is developing an economical PEM fuel cell system based on autothermal cyclic reforming (ACR), which is more economical than conventional reforming technology at small scale.

Widespread use of hydrogen-based fuel cells to power passenger cars and light trucks is a major objective of federal energy policy and is also a key element of AQMD's long-term strategy to comply with air quality standards that will take effect in the 2020 timeframe. The ACR technology may provide an economical means for distributed production of hydrogen from conventional fuels at vehicle fueling stations.

Project Objective
The objective of this project was to demonstrate an integrated ACR-PEM fuel cell system producing 10 kW of electric power with 40% overall thermal efficiency, less than 1 ppm NOx and over 90% availability.

Technology Description
ACR differs from conventional steam-methane reforming in two major aspects. One is that ACR is self-heating, thus eliminating the need for a separately fired furnace. The second is that ACR internally removes CO_2 from the hydrogen-rich gas by reaction with CaO to form $CaCO_3$, greatly reducing the size of downstream gas purification equipment.

Self heating occurs in the first step of the cyclic process by passing air over the nickel catalyst, which produces heat from oxidation of the nickel to nickel oxide. This step also converts $CaCO_3$ back to CaO and releases the CO_2. In the second step of the cycle, the nickel oxide is converted back to metallic nickel by exposure to a small amount of methane. The final step is the reforming step, in which steam and methane are passed over the hot nickel catalyst, producing a hydrogen-rich gas also containing CO and CO_2.

Since PEM fuel cells have a low tolerance to CO, the hydrogen-rich gas is subjected to two CO removal steps in series—a shift reactor and a preferential oxidation (PrOx) reactor.

Status
The project was terminated before attainment of the objectives because the contractor was unable to achieve sustained operation of the ACR.

CEC's interest in this project was focused on the ACR alone, as an economical method of distributed hydrogen production for vehicle fueling stations. CEC had a separate contract, although much of the effort was in common with

the contract funded by CARB and AQMD. The contractor completed the CEC project, and has submitted a final report on that work.

Results

Due to equipment problems, only short-duration operation of the integrated ACR system (ACR and CO removal reactors) was achieved. The PEM fuel cell was tested on simulated ACR system outlet gas, but operation of the integrated ACR-PEM fuel cell system was not achieved. Table 1 summarizes the results of the project.

Table 1. Results

Parameter	Target	Result
ACR Outlet Gas	>65% H2 <15% CO	Achieved
Shift Outlet Gas	<2% CO	Achieved
PrOx Outlet Gas	<10 ppm CO	Not Achieved
PEM Fuel Cell	Operate on expected ACR system gas	Requires modifications but expected to work
System Efficiency	40%	30-35% (calculated)
Availability	90%	Not Determined
NOx	<1 ppm	Not determined

Benefits

The ACR-PEM technology, if successfully developed and commercialized, could provide a means for producing on-site power for residential and small commercial buildings with almost no pollutant emissions. The ACR might also constitute a more economical means for distributed production of hydrogen for fuel-cell vehicle fueling stations.

Based on projected emissions in the year 2020 in AQMD's draft 2007 AQMP, reductions of NOx and VOC emissions could be as high as 1.9 and 5.7 tpd, respectively, if ACR-PEM technology displaced 50% of central plant power production (including an estimated 25% displacement of residential fuel burning due to waste heat recovery). If ACR-PEM technology displaced 75% of conventional passenger cars and light trucks by 2020, NOx and VOC reductions could be as high as 70 and 44 tpd, respectively.

Project Costs

CARB and AQMD each had budgeted $100,000 for this project. A total of $110,404 was paid to the contractor for work completed prior to termination of the project. AQMD and CARB each paid $55,202. CARB contracted directly with GE, while they acted as the pass-through agency for AQMD funds.

Commercialization and Applications

The ACR technology needs further development before its potential for commercial viability can be assessed.

AQMD Contract #06075 **August 2006**

Field Comparison of Portable Electrochemical Analyzers to a CEMS for Measurement of NOx and CO Emissions from a Rich-Burn Engine

Contractor

Advanced Engine Technologies Corp.

Cosponsors

Eastern Municipal Water District (EMWD)
Southern California Gas Company (SCG)
Testo

Project Officer

Howard Lange / Alfonso Baez

Background

The South Coast Air Quality Management District (SCAQMD) Proposed Amended Rule 1110.2 Industry Stakeholder Work Group (Stakeholders) submitted proposed emissions monitoring strategies for stationary engines to SCAQMD in support of proposed Rule 1110.2 amendment. This included a series of monitoring demonstration tests. One test addressed the possible use of lower-cost electrochemical cell type emissions analyzers for monitoring rich-burn engines with non-selective catalytic reduction (NSCR) control devices.

Project Objective

The objective of this test was to provide a better understanding of the performance, capabilities and infrastructure requirements for electrochemical cell technology when used on a "semi-continuous basis" on NSCR fitted engines. This evaluation was to help develop an understanding of the gap between the current state-of-the-art portable electrochemical analyzers and the adaptation for its use as a semi-continuous alternative to a continuous emission monitoring system (CEMS) or alternative continuous emission monitoring system (ACEMS).

Technology Description

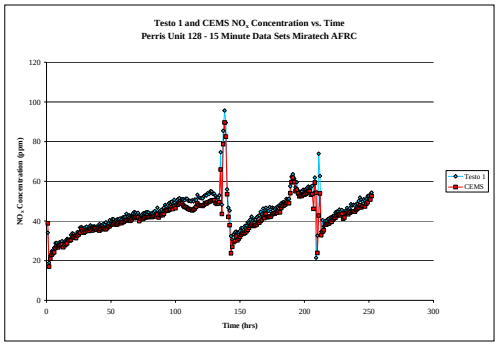
The Testo 350 Xl is a state-of-the-art emission analyzer that incorporates a variety of technologies making it an ideal candidate for this monitoring project. It is self-contained and can measure O_2, CO, CO_2, NO, NO_2, SO_2, H_2S, C_xH_y, temperature, pressure, flow & velocity, as well as provide data acquisition and storage. It utilizes a patented sample conditioning system and sample flow control. To eliminate sensor thermal drift the unit utilizes continuous temperature compensation and sensor temperature control. As the emissions from engines have a potential to vary widely, the Testo 350 incorporates an automatic dilution system that permits the measurement of high concentrations. The unit also incorporates on-board memory capable of storing a month's worth of data at the one record per second level for 15 minutes of every hour. The unit also includes automatic testing programs that will sample exhaust gases and automatically purge the sensor with fresh air.

Status

Advanced Engine Technologies Corporation (AETC) began the test in December 2005. However problems with the test engine necessitated a change to a different engine requiring restarting of the test in February 2006. AETC completed field testing on April 12, 2006 and submitted the final report on August 11 2006. The final report is on file with complete technical details of the project.

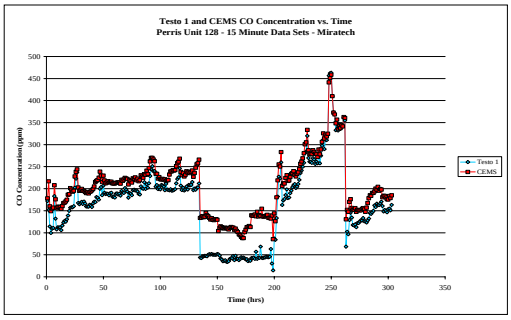
Results-Applicable Only to NSCR

The Testo NO analyzers exhibited excellent performance with good to very good correlation, low variability and slightly high bias (5-10%). Uncontrolled ambient environment did not impact system performance.



The Testo CO analyzers measured significantly lower values than the CEMS CO analyzer. It appears the CEMS CO analyzer, but not the Testo analyzer, suffers positive cross interference from nitrous oxide (N_2O) which NSCR-fitted engines can generate.

Consequently it is not possible to make any comparative assessment of the CEMS and Testo CO data. The Testo CO cell will probably offer very good performance equal to the NO cell once cross interference issues with the CEMS CO reference method is resolved.



The results indicate calibration gas challenge intervals of at least two weeks appear to suffice using the Testo's normal sample conditioning system. Testo feels longer intervals in the range of one month would probably suffice.

During the 2½ month duration of the test the two Testo analyzers suffered five CO cell failures and two NO cell failures. Some of these failures may have been induced by other equipment malfunctions and/or the operator's misunderstanding of the purge and dilution requirements. However it appears that even brief uncontrolled emissions excursions bias and even poison the CO cells. This needs to be addressed before the CO cell can be reliably used in a semi-continuous monitoring application.

Benefits

The Testo analyzer is not a direct replacement for a CEMS. If properly integrated for semi-continuous monitoring it could potentially serve as a viable alternative for a CEMS. The low initial cost, robustness and overall "plug and play" nature of the Testo package minimizes initial costs and certainly simplifies maintenance in comparison to a conventional CEMS.

Project Costs

AETC proposed performing the work scope for $33,320. Actual costs to complete the project were approximately $46,000. The overages of $13,000 were due to; unanticipated software integration problems with the Testo, the change in engines and the investigation of Reference Method Cross Interference.

Cost share by the co-sponsors includes $16,000 by SCG and $12,500 by EMWD. Testo made a substantial contribution to the project which they consider part of their normal commercial operation and therefore did not quantify.

Commercialization and Applications

Prior to commercialization, Testo must solve the CO cell poisoning problem and develop a suitable reporting user interface. The latter cannot happen until SCAQMD develops draft performance requirements for a semi-continuous monitoring system based on the Testo analyzer. Testo can then modify the system software or commission a third party to develop a suitable reporting package. Testo could also develop a hardened version of the system for outdoor installation.

Of these tasks, the development of performance requirements by SCAQMD is probably the longest lead time and in the critical path. Once developed Testo should be able to address the open items in about six months. The resultant product should be applicable to any NSCR-fitted engine operating at BACT emission levels. Additional testing could extend the qualification to all NSCR-fitted engines operating at higher levels allowed by Rule 1110.2.