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EXECUTIVE SUMMARY

The SCAQMD executed 55 new or amended contracts during calendar year 2001 to sponsor research, development, and demonstration (RD&D) and commercialization of alternative fuel and clean fuel technologies in Southern California. Tables 1 and 2 list these contracts which are further described in this report. The SCAQMD contributed more than $6 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 $19 million. These projects addressed a wide range of issues with a diverse mix of advanced technologies. The areas of technology advancement included:

- Alternative Fuel On-Road Applications, particularly in the heavy-duty vehicle sector;
- Alternative Fuel Infrastructure Development, particularly for CNG and LNG fuels;
- Fuel Cell Vehicles and Hydrogen Fuel;
- Electric Vehicle and Hybrid Electric Vehicle Technologies;
- Alternative Fuel Off-Road Applications, particularly for heavy-duty construction equipment;
- Emissions Analysis and Health Effects; and
- Technology Transfer and Assessments.

In addition, 21 research, development, and demonstration projects and 32 technology assessment projects or studies were completed in 2001, as listed in Table 4. Summaries for technical projects completed in 2001 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, 2002, after approval by the Board at a public hearing.

CLEAN FUELS PROGRAM

An Overview

Summary

This report summarizes the progress of the South Coast Air Quality Management District (SCAQMD) Clean Fuels program for calendar year (CY) 2001. This SCAQMD program cosponsors projects to develop, demonstrate, and expedite the implementation 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, 2001 and December 31, 2001, the SCAQMD executed 55 contracts that supported clean fuels and advanced technologies. The SCAQMD contributed more than $6 million towards these contracts that had a total project cost of nearly $19 million. These contracts addressed 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 expenditures, and outlines future plans for the program.

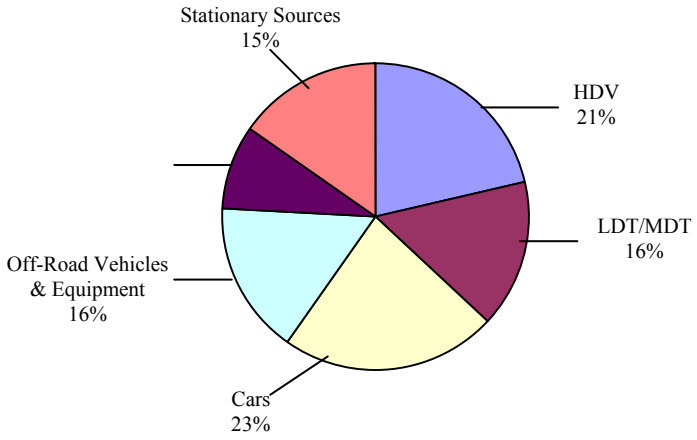
The content of this report addresses the requirements set forth in state legislation passed during 1999 that amended and extended the Clean Fuels Program. Specifically, as stated in the California Health and Safety Code (H&SC) section 40448.5.1(d), the SCAQMD must submit, on or before March 31 of each 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 automobile 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.

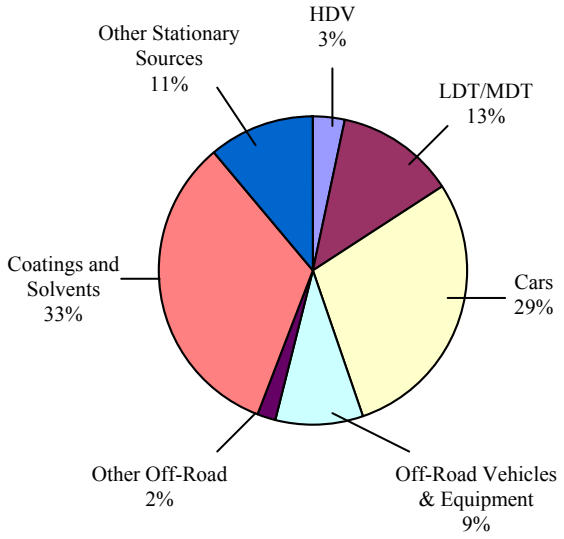
The Need for Advanced Technologies

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 Basin emissions inventory and the target emissions projected by the 1997 Air Quality Management Plan (AQMP) to attain air quality standards with further amendments in 1999. The projected baseline inventory, based on 1997 projected emissions, is shown in Figure 1. From this baseline of 997 tons VOC/day, and 1003 tons NO_x/day the Basin emissions must be reduced to 413 tons VOC/day and 530 tons NO_x/day to attain the national ambient air quality standards. This represents overall reductions of 59 percent and 47 percent for VOC and NO_x emissions, respectively.



Total NO_x Emissions = 1003 tons/day



Total VOC Emissions = 997 tons/day

Figure 1: Projected Basin Emission Planning Inventory for 1997

The 1997 AQMP and the 1999 amendments to that document rely on advanced technologies that are not yet fully developed for commercial use to meet long-term emission reduction measures. These long-term measures represent about 40 percent of the needed NO_x reductions and 50 percent of the needed VOC reductions to achieve ambient air quality standards in the Basin by 2010. All of the long-term NO_x reductions are from mobile sources, while 65 percent of the required long-term VOC reductions are expected from stationary sources.

- The new air quality standards for ozone (0.08 ppm 8-hour average) proposed by the U.S. Environmental Protection Agency (EPA) in 1997 are projected to require additional long-term controls for both NO_x and VOC.

Mobile Source Inventory Model EMFAC2000 (Version 2.01) estimates the following levels of emissions in tons/day from mobile sources for the years 2000 and 2010:

	2000	2010
VOC	552	260
Carbon Monoxide	5676	2615
Oxides of Nitrogen	745	428
PM_{10}	25	26

To help meet the need for technology to address the attainment of clean air standards in the South Coast Air Basin (Basin), the Governing Board adopted a Clean Fuels Program and established the Technology Advancement Office in 1988. This program is intended to assist in the rapid development and deployment of progressively lower-emitting technologies and fuels through an innovative public-private partnership. Since its inception, the SCAQMD Technology Advancement Office has co-funded projects in a cooperative partnership with private industry, technology developers, academic and research institutes, and local, state, and federal agencies. This public-private partnership has enabled the SCAQMD to leverage its public funds with outside investment.

Program Funding

The Clean Fuels Program, under California Health and Safety Code (H&SC) 40448.5 and 40512 and Vehicle Code 9250.11, establishes mechanisms to collect revenues from mobile and stationary sources to support the program's objectives, albeit with constraints on the use of the funds. The objective of this program is to support and promote projects to increase the utilization of clean-burning alternative fuels and related technologies, such as methanol, fuel cells, liquid petroleum gas, natural gas, combination fuels, synthetic fuels, electricity including electric vehicles, hydrogen, and other clean alternatives yet to be developed.

This program imposes a $1 fee on the renewal of registration of motor vehicles registered in the SCAQMD to fund this effort. Revenues collected from these motor vehicles must be used to support mobile source clean fuel projects. In addition, emission fee surcharges under this Clean Fuels Program are imposed on stationary sources emitting more than 250 tons of pollutants per year within the SCAQMD to support related stationary source clean fuel technology developments. As noted previously, the Clean Fuels Program was amended with the passage of Senate Bill (SB) 98, authored by Alarcon, on June 8, 1999, that extended this funding mechanism until January 1, 2005. Projected funds available annually for related Clean Fuels research and development projects from this revenue source are approximately:

- Mobile sources (DMV revenues) $10,600,000
- Stationary sources (emission fee surcharge) $400,000

The estimated uncommitted balance in the Clean Fuels Fund at the close of 2001 was $9.9 million. 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 budget. Historically, such cooperative project funding revenues have been received from the California Air Resources Board (ARB), California Energy Commission (CEC), the U.S.

Environmental Protection Agency (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.

Another limited revenue source available to fund the development and demonstration of advanced clean air technologies is the Advanced Technology Fund. This fund was established as a special revenue fund, separate from the SCAQMD budget, for revenues received as a result of penalties and settlements from violations of air pollution control rules and regulations. In some cases, the revenues from violations may be tied to specific technologies or the development of technologies to address specific industrial needs. In certain enforcement cases, for example, instead of simply paying a fine a company could place the penalty amount into this fund and help develop low-emission processes in its own field of business. The estimated uncommitted balance in this fund at the close of calendar year 2001 is $ 147,000.

The final, and perhaps most significant, funding source can best be described as an indirect source; that is, 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 at least $4 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, including technologies to reduce VOC emissions from stationary and area sources.

A second advisory group was formed in response to requirements specified in SB 98 (Alarcon). Under H&SC 40448.5.1(c), an advisory group was specified to 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, the Technology Committee of the SCAQMD Board, public hearing of plans and reports before the full SCAQMD Governing Board, and submittal of annual reports to the Legislature.

Core Technologies

The SCAQMD continually seeks to support the deployment of lower emitting technologies. The technology advancement program is shaped by two basic factors:

- The low- and zero-emission technologies needed to achieve clean air standards in the Basin; and

- The funding available to support technology development within the constraints imposed by that funding.

The SCAQMD program tries to maintain a flexible program to address dynamically evolving technologies and the latest progress in the state-of-the-art. 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. As a result, the SCAQMD program must be flexible to accommodate these changes in direction. 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.

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 the common approach of "pollution prevention," that is, inherently low- or zero-emission technologies rather than after-treatment technologies intended to reduce emissions after they are formed. Historically, mobile source projects have targeted low-emission 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 and energy storage/conversion devices (e.g., fuel cells and batteries); and implementation of clean fuels (e.g., methanol, natural gas, propane, and hydrogen), including their infrastructure development. Stationary source projects have included a wide array of advanced low NO_x technologies, low VOC coatings and processes, and clean energy alternatives, such as fuel cells, solar power, and other renewable energy systems.

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.

Alternative Fuel Heavy-duty Vehicles

Heavy-duty vehicles are significant contributors to the Basin's on-road vehicle emissions inventory, contributing over one-third of the NO_x and two-thirds of the particulate emissions. These heavy-duty vehicles are primarily powered by diesel-fueled compression ignition engines, which in addition to emitting NO_x and PM, produce exhaust constituents that are toxic substances. The 1997 AQMP projects that significant long-term emission reductions will be required from mobile sources, especially from the heavy-duty sector, to attain 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 4.0 g/bhp-hr; whereas natural gas fueled engines with after-controls can potentially achieve emissions as low as 0.5 g/bhp-hr. The SCAQMD, along with various local, state and federal agencies, have supported development and demonstration of alternative fuel heavy-duty engine technologies, including methanol, compressed and liquefied natural gas, and propane. CNG and LNG heavy-duty vehicles are finding many applications in urban fleets, such as transit buses, refuse collection, and delivery vehicles. Micro-turbines are also showing great promise as a low-emission alternative to the internal combustion engines, when powered by natural gas or propane. 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.

Alternative Fuel Infrastructure

A key element for the widespread acceptance and resulting increased use of alternative fueled vehicles is the infrastructure to support the refueling of vehicles by the driving public. The refueling infrastructure for gasoline and diesel fuel is well established and accepted by the public. Alternative, clean fuels such as natural gas, methanol, ethanol, propane, hydrogen, Hythane™ , 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 develop enabling technologies for refueling and recharging of alternative fuel vehicles (AFVs) and electric vehicles (EVs) and to expand the infrastructure to support zero and near-zero emission vehicles.

The SCAQMD has recently embarked on a ‘ground-breaking’ endeavor to add and upgrade natural gas fueling facilities to support the need for CNG and LNG fuel by fleet operators who are subject to clean-fuel fleet requirements. In addition, work has also started on developing a series of hydrogen fueling sites for use by the early prototype fleet of fuel cell cars and buses in the future.

Fuel Cells and Hydrogen

Fuel cells are devices in which chemical energy is converted into electrical energy without combustion. In a PEM fuel cell for example, a fuel, usually hydrogen, reacts with oxygen to produce electrical power and pure water with essentially no emissions. These ultra-clean and high-efficiency electrochemical engines can provide excellent performance along with rapid refueling for vehicles, and have the potential to work in virtually every mobile and stationary application currently powered by internal combustion engines. Consequently, they are specifically identified in the AQMP as "enabling" technologies to help meet long-term control measures in the transportation sector.

Fuel cells are emerging as a leading alternative technology to power zero emission vehicles (ZEVs) and near-ZEVs. Despite the considerable work done and recent announcements of international joint ventures, a great deal of additional development is needed to improve and demonstrate the ultimate commercial viability of fuel cells for transportation applications. It appears that cars, buses, and distributed power generation will be the first beneficiaries of this exciting new technology. Two of the prime challenges facing the widespread potential usage of fuel cells are the fuel infrastructure development and the relatively high cost of this technology.

Electric and Hybrid Electric Vehicles

Electric Vehicles (EVs) are powered by an electric motor instead of an internal combustion engine. The electrical energy is supplied from an on-board energy storage device such as a battery. Hybrid electric vehicles (HEVs) add an engine-alternator system with fuel storage for

onboard recharging of the batteries to extend vehicle range, increase fuel efficiency, and minimize emissions compared to conventional vehicles. In HEVs, the engine is typically small and may be powered by gasoline, natural gas, or fuel cells. Both EVs and HEVs are usually equipped with regenerative braking that reverses the field of the electric motor during vehicle braking so that it functions as a generator to recharge the batteries and extend vehicle range.

The AQMP projects the need for significant penetration of zero emission technologies, including EVs, in the Basin to achieve state and federal clean air standards. Although original equipment manufacturers (OEMs) are beginning to introduce limited quantities of EVs and HEVs in Southern California to meet the terms of the Memoranda of Agreement with the ARB, there remains a need to support advancement of EV technologies to improve marketability and expedite their implementation. The SCAQMD continues to support projects to develop and demonstrate such advancements in electric drive trains, energy storage devices, charging infrastructure, and related components. In addition to passenger vehicles, other applications for EV technologies are evolving, albeit slowly.

Off-Road Applications of Alternative Fuel Technologies

Off-road mobile sources refer to aircraft, locomotives, marine vessels, farm and construction equipment, industrial equipment, and utility and lawn-and-garden equipment, as well as off-road vehicles. This broad category represents about 25 percent of the total NO_x emission inventory and 11 percent of the total VOC inventory in the Basin. Much of the equipment in this source category is either uncontrolled and unregulated or controlled to a much lesser extent than on-road vehicles. The authority to develop and implement regulations for these off-road mobile sources lies primarily with the EPA and the ARB, and to a lesser extent with the SCAQMD.

For example, the ARB adopted emission standards for utility and lawn and garden equipment that became effective in 1995, with more stringent standards to take effect in 1999. The EPA has also proposed a national program for such engines in its FIP strategy. Such standards may eliminate hand-held, two-stroke engines and the associated equipment they power because of the lack of satisfactory, low-cost emission control equipment. The greatest need and opportunity for emission reductions may well lie with off-road sources subject to federal control or international agreements.

Low-emission and clean-fuel technologies that appear promising for on-road mobile sources should also be effective at reducing emissions from a number of off-road sources. Clean fuels such as natural gas, propane, methanol, ethanol, hydrogen, and Hythane™ may provide an effective option to reduce emissions from some off-road fleet applications. In addition, reformulated gasoline and diesel fuels have been developed to lower emissions and, when used in conjunction with advanced emission controls, additives, and new engine technologies, appear to have promise. The U.S. EPA and the SCAQMD, for example, has promulgated regulations that lower the sulfur content of diesel fuels in the future. Immediate benefits are also possible from particulate traps, fuel additives and emulsifiers that have been developed for diesel fuel applications.

Clean Energy Technologies for Stationary Sources

Given the limited funding available to support low emission stationary source technology development, this technical area is not a high priority area. To gain the maximum air quality benefit in this category, higher-polluting fossil fuel-fired electric power generation needs to be replaced with clean renewable energy resources or other advanced zero emission technologies, such as:

- Fuel Cells

- Solar, Wind, and Geo-thermal Energy
- Bio-mass Conversion

Distributed generation with the help of fuel cells or renewable resources also holds the promise of significant emission reductions by displacing generation from older, higher-polluting central power plants.

Although combustion sources are lumped together as stationary, the design and operating principles vary significantly. Included in the stationary category are continuous combustion devices, such as boilers, heaters, and 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 technology for this category would focus on using advanced combustion processes, development of catalytic add-on controls, and alternative fuels and technologies.

VOC and PM Reduction Technologies for Stationary Sources

The broad category of VOC reduction technologies is developing and emerging in response to technology-forcing control measures and rules, business demands for clean non-polluting products and processes that reduce toxic exposure risk for their employees, and general public demand for clean air and a clean environment. A few examples from this broad category of low VOC products and processes include:

- Water-based zero-VOC architectural paints.
- Low-VOC and Zero-VOC wood, metal, and plastics coatings, including Ultra-Violet (UV) and Electron Beam (EB) cured products, water-based coatings, and powder coatings. Such coatings are proving to be preferred for a number of reasons including performance, reduction in worker exposure to toxic materials, and easier compliance with air, water, and other regulations.
- Aqueous cleaning solutions and processes, such as steam cleaning, as alternatives to conventional petroleum solvent cleaning operations.

Although progress is being made in the development and commercialization of zero-VOC products and processes, further technology advancements are needed to achieve the AQMP goals. Future technology priorities will focus on "pollution prevention" technologies, which appears to be the most promising approach for this diverse and ubiquitous source category.

PROGRAM IMPACT

Benefits of the Clean Fuels Program

The SCAQMD Clean Fuels Program continually seeks lower emitting technologies. Overall program direction reflects the technology needs identified in the AQMP; state and federal regulatory developments; annual research and development coordination meetings with the ARB; periodic meetings with various technology, clean fuel, and industry working groups; review of technical papers and scientific journals; participation in technical exchange conferences; and periodic meetings with the Technology Advancement Advisory Group and SB 98 Clean Fuels Advisory Group.

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 possibility, and consistency with program goals and funding constraints.

Commercialization and implementation of advanced technologies come with several real-world challenges and barriers to be overcome. Recurring barriers to the successful commercialization of new technologies include:

- Cost/Economics
- Real-world demonstration requirements
- Technical performance
- Fuel and Support Infrastructure
- Regulations
- Safety
- Certification and liability, and
- Consumer acceptance.

The reluctance of manufacturers as well as end users to invest in advanced technology products must be overcome by a combination of real-world demonstrations, education and outreach, and regulatory mandates and incentives. The SCAQMD's role in technology advancement is to share the risk of emerging technologies by cost-sharing the development and demonstration projects that address these barriers.

One way to assess the impact and benefits of the SCAQMD program is to provide specific examples of accomplishments and commercial, or near-commercial, products supported by the SCAQMD Clean Fuels Program.

Research and Development Programs

The development of advanced technology faces increasing challenges in these times of diminishing resources, infrastructure and energy uncertainties, sensitivity to multi-media environmental impacts, and the need to find balance between the environment and the economy. 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-art 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 the ARB, the CEC, the EPA, and the 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 APCDs and AQMDs; National Association of Fleet Administrators (NAFA), major local transit districts, and local gas and electric utilities. The list of organizations with which the AQMD coordinates research and development activities also includes the organizations specified in H&SC 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 formally meets with the ARB 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), Electric Power Research Institute (EPRI), and Gas Research Institute (GRI).

The coordination efforts with these various funding organizations have resulted in a number of cosponsored projects. The descriptions of the projects awarded in CY 2001, found in the next section of this report, list the cosponsors and subcontractors for each project. 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 to help expedite the implementation of advanced low-emission technologies. Listed below are the funding agency partners and major manufacturers actively involved in SCAQMD projects for this reporting period. It is also important to note that, although not listed below, the technology developers, smaller manufacturers, and other project participants listed in the project descriptions all make important contributions critical to the success of the SCAQMD program.

Research Funding Organizations **Major Manufacturers**

California Air Resources Board
California Energy Commission
Coordinating Research Council
Defense Advanced Research Projects Agency
Electric Power Research Institute
Gas Research Institute
Gas Technology Canada
Los Angeles Department of Water and Power
National Renewable Energy Laboratory
New York Power Authority
Sacramento Metropolitan AQMD
San Diego APCD
Southern California Edison
Southern California Gas Co.
U.S. Department of Energy
U.S. Department of Transportation
U.S. Environmental Protection Agency
U.S. Postal Service
Caterpillar
Cummins Engine Company
Detroit Diesel Corporation
Engine Manufacturers Association
General Motors
IMPCO Technologies
Mack Trucks
PACCAR
Siemens-Westinghouse
Solar Turbines

Important examples of the impact of SCAQMD research and development coordination efforts is the continued focus of heavy-duty engine manufacturers and end-users on low-emission alternative fuel engines and PM reduction from off-road heavy-duty construction equipment.

Alternative Fuel On-Road Engines

The SCAQMD and others have long supported the development and demonstration of natural gas heavy-duty engine technology. Over the past decade, major U.S. engine manufacturers have developed a first generation of heavy-duty natural gas engines for use in transit buses and heavy-duty commercial trucking. The current generation of natural gas engine technology can achieve emissions below 2.0 g NO_x/bhp-hr, however, there is a significant engine performance and efficiency penalty to achieve those levels. Conversely, if engine performance is optimized, emissions increase. Furthermore, additional work is needed to lower the NOx emissions to 0.5 and ultimately 0.2 g/bhp-hr, and lower the PM emissions to 0.01 g/bhp-hr to meet future heavy-duty vehicle standards. These technology barriers currently inhibit strategies to encourage wide-scale use of natural gas in intra- or inter-state trucking operations.

As a specific example, in 2001, the SCAQMD formally joined with CEC, CARB, and Detroit Diesel Corporation (DDC) to cosponsor a $3.5 million project to develop very low emission heavy-duty natural gas engines. While this project was previously approved in 2000, the SCAQMD Board further augmented the funding in 2001 to achieve an expedited natural gas engine introduction for the 2003 model year. The SCAQMD contribution of about $1 million is matched by co-funding of about $2.5 million from CEC, CARB, and DDC.

The goal of the DDC project is to develop the Series 50G natural gas engine with an advanced fuel control system to achieve 300 hp and 900 ft-lb torque. This engine is intended to be certified to 0.5 g/bhp-hr NOx emissions. This development will utilize new engine system design that will run the engine at the leanest possible air-to-fuel ratio under any condition. New technology to optimize the combustion stability and extend the engine's lean misfire limit will be also developed. The DDC Series 50G engine is widely used in the bus market and the technology may also be extended to the Series 60G engine used in heavy-duty trucks.

PM Reduction from Off-Road Heavy-Duty Equipment

The contribution of heavy-duty diesel construction equipment and off-road engines to the NOx and PM emissions inventory has been disproportionately high, and is expected to increase. According to a recent SCAQMD study, diesel emissions contribute about 70 percent of the cancer risk attributable to air toxics in South Coast Air Basin. Significant emission reductions can be obtained from the largely uncontrolled or unregulated heavy-duty diesel powered construction equipment with the help of after-treatment technologies and low-sulfur diesel fuels.

For example, in 2001, the SCAQMD, in partnership with the CARB, Sanitation Districts of Los Angeles County, and others, cosponsored a project to demonstrate the viability of passive particulate trap technologies on existing heavy-duty construction equipment fueled by low-sulfur diesel. PM reductions in excess of 80 percent are expected in this demonstration project with 17 in-use off-road construction equipment using 22 diesel engines. Effects of both P-traps and low sulfur diesel containing less than 15 ppm sulfur, will be assessed. The SCAQMD contributed $489,143 to this $910,000 project.

Technology Commercialization

It is the specific function of the Clean Fuels Program to help expedite the commercialization of low- and zero-emission technologies and fuels needed to meet the requirements of the long-term 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. When such projects are completed, an assessment is performed to determine the feasibility of incorporating the technology into rule development. If the technology appears feasible, future rule development is recommended to realize the emission reductions associated with the corresponding long-term measure. Thus, the advanced technology projects funded are an important and necessary process towards implementation of the clean air goals of the AQMP.

Projects designed to develop and demonstrate prototype low-emission technologies are inherently difficult to quantify with respect to cost effectiveness, i.e. dollars spent per ton of pollutant reduced. For example, if a project leads to the successful development of a prototype electric vehicle, the avoided emissions from that single vehicle are trivial compared to the overall environmental benefit. The true measure of success for the project lies in whether or not the corresponding ZEV technology has been significantly advanced and/or accelerated towards commercialization. Since commercialization may come years later, after many iterations of technological development, this can be difficult to measure or quantify. Thus, assessing the value of the original project in terms of its cost per ton of emissions reduced is not a true measure of success of the project.

The following examples, however, demonstrate the impact of the SCAQMD program on technology commercialization during the CY 2001 reporting period.

Heavy-Duty Engine Development

The development and demonstration of low-emission medium- and heavy-duty engines has been a priority of the SCAQMD Clean Fuels Program since its inception. These engines are used in numerous commercial activities including local pick-up and delivery trucks, heavy-duty truck tractors for pulling trailers and shipping containers both in the Basin and long-haul, transit buses, shuttle buses, yard tractors at shipping points, and dockside equipment at the ports. Through projects directly with Original-Equipment Manufacturers (OEMs) or with intermediate developers such as the Gas Research Institute, Southern California Gas Company, Acurex Environmental (A.D. Little, ARCADIS) and others, SCAQMD has supported the ultimate commercialization of the following engines:

- Cummins B5.9G (CNG), B5.9LPG (LPG), L10G (CNG), C8.3G (CNG)
- Detroit Diesel Corporation Series 60G (CNG/LNG), Series 50 G (CNG/LNG)
- Deere 6068 (CNG), 6081 (CNG)
- Mack E7-400 G (LNG)
- Power Systems (Caterpillar) 3126B (Dual Fuel), C-10 (Dual Fuel), C-12 (Dual Fuel)

These engines are the backbone of the SCAQMD's 1190 series rules that require specific fleets to purchase alternative fuel vehicles. This year, a project with Cummins was completed which supported the development of the next-generation of electronic controls for the C8.3G natural gas engine. This technology is now being commercialized on new natural gas engines. A newly inaugurated project with DDC is developing CNG and LNG heavy-duty engines which will meet the 2007 NOx standard with the 2003 model year natural-gas engines (0.5 g/bhp-hr NOx). Other new projects involve development of the GM 6.0-liter natural gas engine and the Cummins 5.9-liter natural gas engine, both medium-duty engines. Today, natural gas engines power thousands of transit buses, delivery trucks, refuse trucks and street sweepers in the Basin, as a result of SCAQMD's support.

The Carl Moyer Program

In early 1999, the ARB established the Carl Moyer Memorial Air Quality Standards Attainment Program (Moyer Program) to provide incentives to accelerate the implementation of such low emission heavy-duty vehicles, off-road vehicles and equipment, and for fueling infrastructure support. The ARB has established overall program requirements and allocates funds to local air districts, including the SCAQMD, for local program administration. The Moyer Program subsidizes the incremental cost between a low-emission alternative fuel engine and a new diesel engine.

Governor Davis and the Legislature have placed $16 million in ARB's FY 2001- 02 budget to continue this incentive program for low-emission heavy-duty vehicles. The SCAQMD released an RFP in December 2001 to solicit projects for FY 2001-02 Moyer Program funding at a cost not to exceed about $ 11.5 million for vehicle and equipment incentives. As a substitute for the local match requirement, SCAQMD has spent $3.5 million on alternative fuel infrastructure development. The RFP solicits projects for on- and off-road vehicles and equipment, including

refuse haulers, over-the-road trucks, transit buses, construction equipment, marine vessels and port applications, and other vehicles and equipment. New engines, re-powers, and retrofits are allowed within the program.

Despite the success of the Carl Moyer Program, the demand for alternative fuel engines is still low compared to diesel engines; however, the Carl Moyer Program provides a clear indication to heavy-duty engine and equipment manufacturers that end users are willing to choose competitively priced equipment. Significant numbers of new and upgraded natural gas refueling stations are also being built with SCAQMD support in response to market demand for alternative fuels by fleet operators.

Electric Vehicle Application

SCAQMD has supported the development and demonstration of electric vehicle applications for a long time.

In 1999, the United States Postal Service initiated the "Electric Carrier Route Vehicle" project in which it planned to deploy up to 6,000 new electric mail delivery vehicles at post offices nationwide over five years. Phase 1 called for the deployment of 500 vehicles, with an option to provide additional 5500 vehicles pending their satisfactory performance in Phase 1. Ford Motor Company was competitively selected to supply the specialty vehicle based on the Ford Ranger EV light duty truck.

Up to 400 of the first 500 vehicles will be demonstrated within the SCAQMD area. USPS selected Southern California Edison for testing and evaluation of four of the electric mail delivery vehicles, for which SCAQMD provided the funding. The evaluation protocol assessed the electric drivetrain, battery pack, and chassis performance based on the Department of Energy "EV America Protocol."

The evaluation by SCE has shown that the electric mail delivery vehicles met or exceeded all of the baseline performance standards set by USPS. Accelerated testing, which quickly adds miles to the vehicle over a consistent test route, has provided insight into how the vehicles may perform on a longer term basis and encouraged project participants to proactively address many issues. Improvements made to these specialty vehicles are expected to yield benefits in other electric drivetrain vehicles. Many of these technological advances may find application in a variety of hybrid electric vehicles powered by non-internal combustion engines such as microturbines and fuel cells.

2001 PROJECT EXPENDITURE

Description of New Technology Development Projects

A technology-driven approach was continued in 2001, with the SCAQMD supporting clean fuels and technologies that appear to offer the most promise in reducing emissions, promoting energy diversity, and, at least in the long term, providing cost-effective alternatives to current technologies. Given the evolving nature of technology, such a representation is only a "snapshot-in-time". While the SCAQMD has always sought breadth in its project selection in an attempt to address the myriad of sources that contribute to air pollution in the Basin, such technology distributions have necessarily evolved and changed to reflect progress and market conditions.

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, 2001 through December 31, 2001, the SCAQMD executed 55 contracts that supported clean fuels and advanced technologies. These contracts are listed in Tables 1 and 2.

Project expenditures for research, development, and demonstration (RD&D) contracts initiated or amended with dollars for the 2001 reporting period were:

Total Cost of Projects	$18,891,837
SCAQMD Clean Fuels Fund Contribution	$6,128,218

Partially included with the SCAQMD contribution are supplemental revenues from various organizations that supported these technology advancement projects. This supplemental revenue is listed in Table 3, but not all of the funds received have passed through in contracts executed in 2001. Appendix B lists all Clean Fuels Fund contracts that are open and active as of January 1, 2002.

The average SCAQMD contribution was about 35 percent of the total cost of the projects, or each dollar from the SCAQMD was leveraged with more than two dollars of outside investment. Since the inception of the Technology Advancement program, about four dollars of outside funding has been received for every AQMD dollar, historically. For 2001 this ratio was less because of several local infrastructure development projects and technical assessments in which SCAQMD was the sole or major contributor.

In addition to the RD&D projects discussed above, $7.9 million of Clean Fuels funds was allocated as local match to fulfill the requirements of various incentive programs for replacement of highly polluting diesel engines, as described below.

SCAQMD Governing Board Actions

During 2001 the SCAQMD Governing Board approved a total expenditure of about $7.9 million from the Clean Fuels Program for alternative fuel incentive programs. This included replacement of diesel vehicles and equipment under the Moyer Program (about $ 0.3 million in local matching funds), replacement of older diesel school buses under the School Bus Program (about $2.2 million in local matching funds), and support of alternative fuels infrastructure in the Basin (about $5.4 million).

During 2001 the SCAQMD Governing Board also approved expenditure of about $9 million for RD&D projects in the following areas: alternative fuels-on-road, alternative fuels infrastructure, fuel cells and hydrogen, electric and hybrid electric technologies, alternative fuels-off-road, emissions and health effects, technology transfer and assessments, and stationary source controls. The distribution of the Board-approved funding in these areas is shown in Figure 2 below (note that this figure does not include the local matching funds required for state incentive programs).

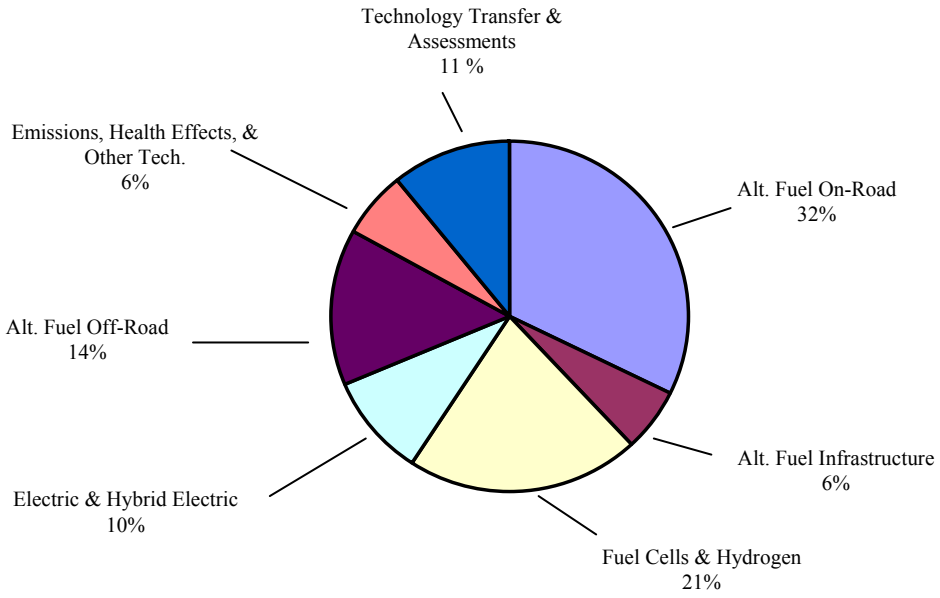


Figure 2: Distribution of SCAQMD Board Approved Clean Fuels Funds for Research, Development, & Demonstration Projects in 2001 ($ 8.98 million)

Contracts Initiated

Due to the legal and administrative requirements for contracting with private, government or academic entities, there is a time lag between approval of a project by the SCAQMD Governing Board and execution of the contract. The amounts of funding may also decrease within the limits approved by Board action, depending on circumstances. Thus, the funding approved by the Board in 2001 differs from the SCAQMD contribution to contracts executed during 2001 due to the nature of the contracting process.

Figure 3 shows the distribution of SCAQMD contributions of about $6.1 million among the major project areas for contracts initiated or amended in 2001. It shows that the SCAQMD contributions were appropriately distributed among the major project areas, in a manner similar to previous year's expenditures, and in keeping with the goals of advancing technologies in several key sectors.

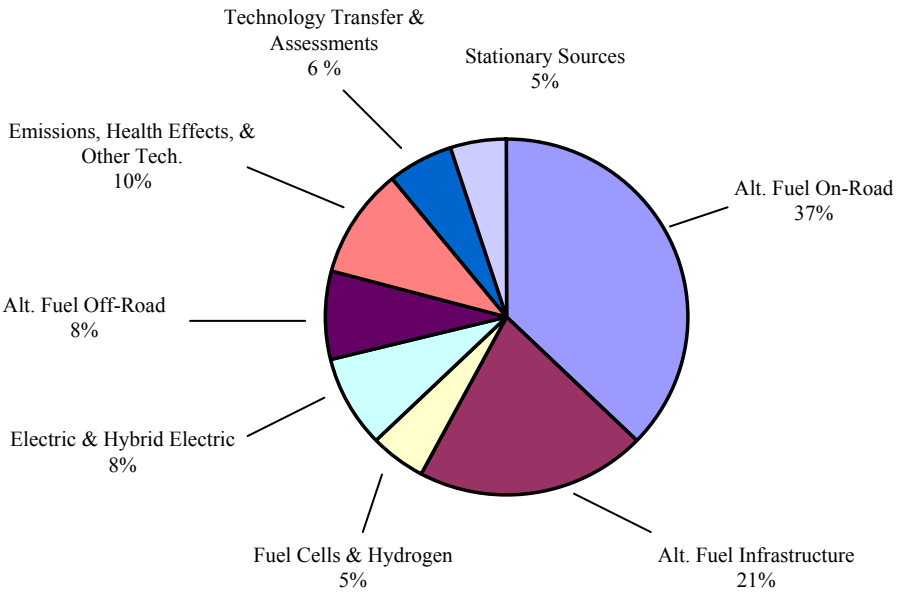


Figure 3: Distribution of SCAQMD Clean Fuels Funds for Research, development, and Demonstration Contracts executed in 2001

Table 1. Contracts Initiated or Amended Between January 1 and December 31, 2001

Contract	Contractor	Project Title	Start Term	End Term	AQMD $	Project Total $
CFM2: Alternative Fuels - On-Road Applications						
01166	Los Angeles Unified School District	Durability Study on a Retrofitted Bus	08/02/01	12/14/01	$74,997	$74,997
01173	National Renewable Energy Lab	Project A: Demonstration of Fischer Tropsch Synthetic Fuel in Heavy & Medium-Duty Vehicles; and Project B: Advanced Diesel Fuels, Engines, Nox Absorber Catalyst & Diesel Particulate Filter Project	06/11/01	07/31/03	$378,001	$2,248,001
01225	Detroit Diesel Corporation	Development of Very Low-NOx Heavy-Duty Natural Gas Engine	04/20/01	05/30/03	$1,830,966	$3,458,150
CFM3: Alternative Fuels - Infrastructure						
01152	Pickens Fuel Corp	Construction Mgmt and Consulting Services for NG Fueling Station and AQMD Headquarters	03/16/01	04/30/02	$26,415	$26,415
01154	R.F. Dickson Company, Inc.	Cost-share Installation of CNG Fueling Facility	08/04/01	07/31/06	$180,000	$180,000
01179	Arthur D. Little Inc	Cosponsor Clean Fuel Infrastructure and Demographic Optimization Study	08/18/01	12/15/01	$25,000	$50,000
01190	USA PRO	Technical and Management Assistance for Infrastructure	06/04/01	06/03/03	$100,000	$100,000
02029	Pickens Fuel Corp	Development and Demonstration of a Universal Card Reader System	12/31/01	05/31/02	$30,000	$65,000
02080	FuelMaker Corporation	Advanced Home Refueling Appliance for CNG Vehicles	11/08/01	06/30/02	$500,000	$1,225,000
02127	Pinnacle CNG Systems LLC	Construction of Fast-Fill CNG Fueling Station at AQMD Headquarters	12/31/01	06/30/02	$395,640	$565,000
CFM4: Fuel Cell and Hydrogen Technologies						
01095	Hydrogen Burner Technology Inc.	Demonstration of a Hydrogen Refueling Station	02/16/01	09/15/03	$300,000	$920,000
CFM5: Electric and Hybrid Electric Technologies						
00164	Electric Power Research Institute	Evaluate Hybrid Electric Vehicles	06/01/01	02/28/02	$50,000	$140,000
01111	Trojan Battery Company	Develop & Demonstrate Advanced Valve Regulated Lead-Acid Batteries	02/22/01	02/28/03	$150,000	$391,000
01208	Southern California Edison Co.	Development & Demonstration of Grid-Rechargeable Hybrid-Electric Utility Service Truck & Mobile Electric Power Supply	08/10/01	05/01/02	$266,348	$532,695

CFM5: Electric and Hybrid Electric Technologies (cont'd)

02116	Clean Fuels Connection Inc.	Development of Dual Inductive/Conductive Charger Bracket to Allow Reduction of EV Charging Infrastructure Costs	12/31/01	03/28/03	$47,815	$95,694

CFM6: Alternative Fuels - Off-Road Applications

02119	Booz-Allen & Hamilton Inc.	Demonstration of Particulate Trap Technologies	12/21/01	01/21/03	$489,143	$910,000

CFE: Emissions Analysis and Health Effects

01140	West Virginia University	Analysis of Exhaust from CNG-fueled Buses	05/22/01	06/30/02	$48,000	$570,000
01141	Desert Research Institute	Chemical Analysis of Exhaust Samples from CNG Buses	05/21/01	02/28/02	$63,543	$63,543
01144	University of California Davis	Ames Bioassay Analyses on Diesel- and CNG-Fueled Bus Exhaust Samples	09/07/01	04/30/02	$51,979	$51,979
01209	University of California Riverside	Study of Children's Pollutant Exposures During School Bus Commutes	06/25/01	04/30/03	$58,992	$509,000
02117	University of Southern California	Deployment & Operation of Scanning Mobility Particle Sizers & Low Temperature Tapered Element Oscillating Microbalance in Children Health Study Communities	09/01/01	10/31/04	$120,000	$194,649
02130	Optical Scientific Inc.	Determination of Ammonia and Methane Emissions from Greenwaste Composting	11/05/01	03/30/02	$50,000	$50,000

CFO: Other Advanced Technologies

01036	Los Angeles Unified School District	Demonstration of School Buses Retrofitted with PM Reduction Technologies	03/26/01	12/15/01	$15,000	$15,000
01057	Engelhard Corporation	Demonstration of School Buses Retrofitted with PM Reduction Technologies	09/21/01	02/28/02	$72,500	$145,000
01032	Johnson Matthey	Demonstrate School Buses Retrofitted with PM Reduction Technologies	12/31/01	02/28/02	$89,000	$202,000
01158	University of California Riverside	Evaluation Of School Bus Retrofit with Exhaust After Treatment Devices	05/18/01	02/14/02	$49,341	$49,341

CFT: Technology Transfer and Assessments

01026	Bevilacqua-Knight, Inc.	Program Support for California Fuel Cell Partnership	12/18/00	12/31/03	$88,000	$1,672,000
01076	Information Television Network	Cosponsor Documentary on The Clean Air Act	01/19/01	05/31/01	$29,500	$157,250
01091	Coordinating Research Council Inc	Cosponsor the 11th CRC Emissions Workshop	02/06/01	09/30/01	$10,000	$105,500

CFT: Technology Transfer and Assessments (cont'd)

01110	National Hydrogen Association	Cosponsor 12th Annual US Hydrogen Meeting	02/07/01	09/30/01	$5,000	$140,000
01112	WestStart-CALSTART	Cosponsor Clean Heavy-Duty Vehicles for the 21st Century Conference	02/01/01	10/15/01	$5,000	$300,000
01113	Western Riverside Council of Governments	Cosponsor 3rd Annual Clean Cities Event	02/01/01	04/30/01	$5,000	$40,000
01189	Natural Gas Vehicle Coalition	Cosponsor the 19th National NGV Conference & Exhibition	09/18/01	01/31/02	$5,000	$355,000
01191	SAE International	Cosponsor the SAE 2001 Future Transportation Technology Conference	06/19/01	12/15/01	$2,000	$2,000
01197	Fritz Kalhammer	Clean Fuels Advisory Group Expenses	06/29/01	02/28/02	$4,000	$4,000
01199	Vernon Roan	Clean Fuels Advisory Group Expenses	06/26/01	02/28/02	$3,000	$3,000
01200	Brian Runkel	Clean Fuels Advisory Group Expenses	06/20/01	02/28/02	$1,000	$1,000
01201	Nicholas Vanderborgh	Clean Fuels Advisory Group Expenses	05/29/01	02/28/02	$3,000	$3,000
01218	Los Altos High School	Cosponsor American Solar Challenge	06/22/01	09/30/01	$5,000	$40,000
01221	College of the Desert on behalf of ATTI	Staff Training on CNG Maintenance and Inspections	09/25/01	09/30/01	$25,000	$25,000
02052	Air Products and Chemicals Inc.	Participation in NG-H2 Compatibility Study Team	07/25/01	10/25/01	$11,527	$11,527
02053	Zoellick, Jim	Participation in NG-H2 Compatibility Study Team	07/25/01	10/25/01	$6,291	$6,291
02054	Lehman, Peter	Participation in NG-H2 Compatibility Study	07/20/01	10/25/01	$5,000	$5,000
02068	Center for Hydrogen Safety, LLC - The	Consulting Services for Hydrogen Codes and Standards	08/06/01	11/06/01	$2,500	$2,500
02118	WestStart-CALSTART	Co-Sponsorship the 2nd Annual Clean Heavy Dduty Vehicles for the 21st Century	10/18/01	08/31/02	$5,000	$300,000
02135	SunLine Transit Agency	Cosponsor Educational Outreach Program	11/08/01	03/31/02	$50,000	$548,000
02136	University of California Irvine	Renew Participation For 3 Years in National Fuel Cell Research Center at UCI	11/08/01	10/31/04	$90,000	$1,250,000
02144	Institute of Ecolonomics	Cosponsor The Drive For Life	10/26/01	12/31/01	$5,000	$65,000

Table 2. Advanced Tech. Fund Contracts Executed Between January 1 and December 31, 2001

Contract	Contractor	Project Title	Start Term	End Term	AQMD $	Project Total $
CFO: Other Advanced Technologies						
01090	Los Angeles Municipal Art Gallery	Smog Catcher Project	03/09/01	12/31/01	$4,000	$4,000
01105	Children's Museum of Los Angeles	Implement Children's AQ Initiative	04/11/01	04/10/02	$20,000	$20,000
01106	Discovery Science Center	Implement Children's AQ Initiative	02/14/01	02/13/02	$45,000	$45,000
01107	Natural History Museum of Los Angeles County	Implement Children's AQ Initiative	02/06/01	02/06/02	$20,000	$20,000
01108	Riverside Municipal Museum	Implement Children's AQ Initiative	06/15/01	06/14/03	$20,000	$20,000
01227	San Bernardino County Museum	Clean Air Through Service Learning	08/31/01	08/31/02	$41,000	$41,000
CFS2: Stationary Sources - VOC/PM Reduction Technologies						
01172	Institute for Research & Technical Assistance	Assess, Develop & Demonstrate Low-VOC Cleaning Systems	05/22/01	07/31/03	$149,720	$149,720

Table 3. Supplemental Grants & Revenues Received Between January 1 and December 31, 2001

Revenue Agreement	Revenue Source	Project Title	Contractor	AQMD Project	Total
02149	California Energy Commission	Development of Very Low-Nox Heavy-Duty Natural Gas Engine	Detroit Diesel Corporation	Contract #01255	$200,000
TBD	California Air Resources Board	Development of Very Low-Nox Heavy-Duty Natural Gas Engine	Detroit Diesel Corporation	Contract #01255	$100,000
TBD	California Air Resources Board	Advanced Home Refueling Appliance for CNG Vehicles	FuelMaker Corporation	Contract #02080	$250,000
TBD	California Air Resources Board	Demonstrate Integrated Technology for Control of Odors and VOCs from Metal Casting Operations	Gregg Industries	Contract #TBD	$150,000
02176	California Energy Commission	Development and Demonstration of Aftertreatment Technologies for PM Emissions Control of CNG-Fueled Heavy-Duty Engines	TBD	Contract #TBD	$400,000
02177	California Energy Commission	Evaluate and Demonstrate Exhaust Emission Treatment Technology for Heavy-Duty Natural Gas Engines	Cummins Westport	Contract #TBD	$347,174
02177	California Energy Commission	Develop Preliminary NG Vehicle Designs and Market Introduction Strategies for a Medium-Duty CNG Vehicle and Heavy-Duty LNG Vehicle	Cummins Westport	Contract #TBD	$100,000

Review of Audit Findings

The SCAQMD undergoes regular financial and performance audits required by state law, as well as special audits periodically requested by the state. This subsection briefly summarizes recent audits of the SCAQMD that included the Clean Fuels Program.

Financial Audits

The regular financial audits are conducted annually at the close of the SCAQMD fiscal year by an independent accounting firm. The financial audits include an Annual Financial Report and Single Audit Reports. The firm of Simpson & Simpson conducted the financial audits for the fiscal year that ended June 30, 2001. There were no findings and recommendations with regard to SCAQMD financial statements, which include Clean Fuels Program revenues and expenditures. Simpson & Simpson gave the SCAQMD an "unqualified opinion," which is the highest financial rating obtainable. This has consistently been the result of prior annual financial audits of the SCAQMD.

Special Audits

In 1998, the California State Auditor, Bureau of State Audits conducted a specially requested audit of selected SCAQMD activities, including "Allocating and Managing the Funding of Research, Development, and Demonstration Projects." With respect to the Clean Fuels Program, this extensive audit made no finding regarding allocating and managing research, development, and demonstration projects. The State Auditor did recommend that the SCAQMD improve the reporting of projects and the dissemination of those reports. The SCAQMD has implemented this recommendation by the following actions:

- Preparing two-page summaries upon the completion of every project for distribution to interested parties. The two-page summaries of projects completed during this reporting period are included as Appendix C of this annual report.
- Establishing a special reference section in the SCAQMD library in which all Technology Advancement project final reports are placed for public access. Other dissemination mechanisms are being evaluated, including making reports available on the Internet.

Project Summaries

This sub-section is comprised of summaries of the technology development and demonstration contracts executed during the reporting period of January 1, 2001 through December 31, 2001. These new and amended projects are listed in the order found in the previous tables, that is, by category and contract number. The content of these summaries includes the information specified in the legislation, including project title, contractors and subcontractors, SCAQMD cost-share, co-sponsors and their respective contributions, contract term, and a description of the projects.

CFM2: Alternative Fuels - On-Road Applications

01166: Durability Study on a Retrofitted Bus

Contractor: Los Angeles Unified School District	AQMD Cost-share:	$74,997
Term: 08/02/01 – 12/14/01	Total Cost:	$74,997

The AQMD has sponsored the installation and demonstration of PM traps by two different manufacturers on a number of school buses. In this project, one of the buses retrofitted with particulate trap at the Los Angeles Unified School District will be selected for accelerated mileage accumulation, in order to evaluate the durability of the trap. The bus will accumulate up to 50,000 miles in a short period of time by driving through some representative routes. Emissions measurements will be conducted on a chassis dynamometer at CARB's heavy-duty vehicle testing facility at the beginning and at the end of the project. The results of this project will help determine the commercial viability of the PM trap technology on present heavy-duty on-road bus fleets.

01173: Project A: Demonstration of Fischer-Tropsch Synthetic Fuel in Heavy-Duty Vehicles; and Project B: Advanced Diesel Fuels, Engines, NOx Absorber Catalyst & Diesel Particulate Filter Project for Heavy-Duty Engine Applications

Contractor: National Renewable Energy Laboratory	AQMD Cost-share:	$378,001
Subcontractor: West Virginia University	Cosponsors:	
	US Department of Energy	$1,870,000
Term: 06/11/01 – 07/31/03	Total Cost:	$2,248,001

Gas-to-liquid (GTL) synthetic fuels are one way to commercialize stranded natural gas reserves. As a GTL fuel, Fischer-Tropsch (FT) fuel is derived from natural gas or other materials through a three-step chemical process. FT fuels have good auto-ignition properties and low sulfur and aromatic content that lead to low diesel engine emissions. This project scales up an earlier NREL demonstration study. In this project six trucks and buses will be used to demonstrate FT fuel and compare the emissions of criteria, non-criteria and toxic pollutants between FT and diesel fuel.

01225: Development of Very Low NOx Heavy-duty Natural Gas Engine

Contractor: Detroit Diesel Corporation	AQMD Cost-share:	$1,030,966
	Cosponsors:	
	Detroit Diesel Corporation	$1,627,184
	California Energy Commission	$700,000
	California Air Resources Board	$100,000
Term: 04/20/01 – 05/30/03	Total Cost:	$3,458,150

Detroit Diesel proposes to further develop its Series 50G natural gas engine with an advanced fuel control system. The project goals are to achieve 300 hp, 900 lb-ft torque and certify the emissions from this engine to 0.5 g/bhp-hr NOx. This system will run the engine at the leanest possible air-to-fuel ratio under any set of conditions. A new combustion system will be developed to optimize combustion stability and extend the engine's lean misfire limit. The Series 50G engine is widely used in the transit bus market, and the developed technology can later be

applied to the Series 60G engine for use in class 7 and 8 heavy-duty trucks. This project targets this low-emitting DDC natural gas engine for introduction for the 2003 model year.

CFM3: Alternative Fuels - Infrastructure

01152: Construction Management and Consulting Services for Natural Gas Fueling Station at AQMD Headquarters

Contractor: Pickens Fuel Corp.	AQMD Cost-share:	$26,415
Term: 03/16/01 – 04/30/02	Total Cost:	$26,415

AQMD plans to build and operate a new natural gas fueling station at its Diamond Bar facility that can accommodate the growing District alternative fuel vehicle fleet. Pickens Fuel Corp has been selected to perform construction management and consulting services for the AQMD. Such tasks will include production of the CNG station design drawings, help to select the most appropriate site for the fueling station, and oversee the entire design/ engineering, permitting and field construction process. The design development drawings need to be completed prior to inviting contractors to bid with comprehensive and accurate cost proposals.

01154: Cost-Share Installation of CNG Fueling Facility

Contractor: R.F. Dickson Company Inc.	AQMD Cost-share:	$180,000
	Cosponsors:	
	R.F. Dickson Company	$200,000
	DOE State Energy Program	$150,000
	MSRC	$220,000
Term: 08/04/01 – 07/31/06	Total Cost:	$750,000

R. F. Dickson, as part of the Moyer Program will be constructing and operating a compressed natural gas, public access fueling station. The station will be used to meet the natural gas fueling requirements for the R. F. Dickson Company as well as the Downey School District, Calsan Inc., and Bellflower School District for the term of the contract. The Moyer Program requires local government match funds in order to obtain Moyer funds. These funds help fulfill that requirement. The project is intended to expand the natural gas fueling infrastructure in support of the fleet rules and to assist in growing the natural gas fleets in the basin. The facility has capabilities to deliver CNG between 800 and 3,600 psi.

01179: Cosponsor Clean Fuel Infrastructure and Demographic Optimization Study

Contractor: Arthur D. Little, Inc.	AQMD Cost-share:	$25,000
	Cosponsor:	
	MSRC	$25,000
Term: 08/18/01 – 12/31/02	Total Cost:	$50,000

This study will depict all existing clean fuel facilities and determine their proximity to new and proposed clean fuel fleets. The end user will be able to analyze the demographics within a distance of one, three, and five miles from a particular site. The outcome will aid both public and private entities in planning optimum locations for new infrastructure installations. The interactive nature of the database will allow present and future clean fuel fleet owners to get a better feel of a

prospective fueling station's potential for throughput and balance the needs of fleets throughout the Basin. It will also act as a tool for determining where new stations are needed, publicize new stations, and provide input to existing facilities.

02029: Development and Demonstration of a Universal Card Reader System

Contractor: Pickens Fuel Corp.		AQMD Cost-share:	$30,000
	Cosponsor:		
		Pickens Fuel Corp	$20,000
		MultiForce Inc.	$15,000
Term: 12/31/01 – 05/31/02		Total Cost:	$65,000

At the present time, each natural gas fuel provider has it's own fueling card. The determining factor of fueling card is based on the type of fueling dispenser and card reader equipment located at each fueling site. Equipment providers of dispensers and card readers do not currently share programming data. At this time, there is not a single card available that can be used with all of these types of card readers. This project will develop a seamless card system that can accept any proprietary card including, in a best case scenario, network cards, and, further, to be able to directly bill such card holders for the fuel they are consuming. This will greatly assist the refueling of natural gas vehicles at multiple locations.

02080: Development and Demonstration of Advanced Home Refueling Appliance for CNG Vehicles

Contractor: FuelMaker Corporation		AQMD Cost-share:	$500,000
	Cosponsor:		
		CARB	$250,000
		TPC (Canada)	$375,000
		DOE	$100,000
Term: 11/08/01 – 04/30/02		Total Cost:	$1,255,000

This project will develop and demonstrate a home appliance that can be used by the consumer to refuel a natural gas vehicle at home. The goal of Phase A (which is covered by this contract) is to develop and produce a working alpha unit prototype that is ready for consumer/user testing, over an 18-month period. Phase B, also lasting 18 months, will implement that testing while upgrading and refining the alpha unit into a beta unit prototype that will be used in the final product commercialization. The target price for this appliance is under $1000, and is expected to play a key role in consumer acceptance of natural gas vehicles due to ease of refueling.

02127: Construction of Fast-Fill CNG Fueling Station at AQMD Headquarters

Contractor: Pinnacle CNG Company		AQMD Cost-share:	$395,640
	Cosponsor:		
		CEC	$169,560
Term: 12/31/01 – 06/30/02		Total Cost:	$565,000

Pinnacle CNG Company will secure the permits and construct a turnkey fast-fill CNG vehicle fueling station. The fast-fill dispensers will be 24-hour accessible by the AQMD fleet but public hours of access will be determined based upon security decisions. Access will be provided by a card reader system designed to accept multiple cards including credit cards. Metering design will

accommodate tie-in of advanced metering systems in parallel with the commercial system employed by the facility.

CFM4: Fuel Cell and Hydrogen Technologies

01095: Demonstration of a Hydrogen Fueling Station

Contractor: Hydrogen Burner Technology, Inc		AQMD Cost Share:	$300,000
	Cosponsor:		
		HBT	$620,000
Term: 02/16/01 – 09/15/03	Total Cost:		$920,000

The objective of the proposed project is to demonstrate a hydrogen generation and refueling station based upon Hydrogen Burner Technology's (HBT) stationary reformer. The reformer converts natural gas to hydrogen using an innovative, non-catalytic, partial oxidation technology. Partial oxidation technology, though generally less efficient than steam reforming, could potentially be more cost effective due to reduced capital costs in the smaller system size range.

CFM5: Electric and Hybrid Electric Technologies

00164: Evaluate Hybrid Electric Vehicles

Contractor: Electric Power Research Institute (EPRI)		AQMD Cost-share:	$50,000
Subcontractors:	Cosponsors:		
		EPRI	$90,000
Term: 06/01/01 - 2/28/02		Total Cost:	$140,000

The Electric Power Research Institute has assembled a working group to compare the impacts and benefits of various hybrid electric vehicle (HEV) options. The scope of work includes evaluation of HEV architecture, performance, modeling; and impacts; costs; customer preference; and commercialization issues. AQMD previously provided $250,000 to support this work which focused on a mid-size vehicle platform, although additional data was collected regarding a small car and an SUV platform. This project provides additional funding and time to complete the data analysis for the small car and SUV platforms. This will provide consistent analysis across multiple vehicles and identify/analyze issues specific to small cars and SUVs.

01111: Develop & Demonstrate Advanced Valve Regulated Lead Acid Batteries

Contractor: Trojan Battery Company		AQMD Cost-share:	$150,000
Subcontractors:	Cosponsors:		
		Trojan	$241,000
Term: 02/22/01 - 02/28/03		Total Cost:	$391,000

Additional advancements in battery performance for electric and hybrid electric vehicles are necessary to achieve increased power and extend battery life. Trojan Battery Company and Ensci have demonstrated performance improvements in lead acid battery technology with the unique use of patented additives incorporated into the active material of the battery plates at the 2-volt

cell level. In this two-phase project, commercial prototype 12-volt modules will be developed, assembled and tested as electric vehicle battery packs, and demonstrated and tested in vehicles.

01208: Development & Demonstration of Grid-Rechargeable Hybrid-Electric Utility Service Truck & Mobile Electric Power Supply

Contractor: Southern California Edison	AQMD Cost-share:	$266,348
	Cosponsors:	
	SCE	$112,000
	Capstone Turbine Corporation	$12,550
	Enova Systems	$49,088
	EPRI/CEC	$63,592
Term: 08/10/01 - 05/01/02	Total Cost:	$532,695

SCE will develop a grid-rechargeable hybrid-electric converted standard utility lift truck. The truck will utilize a LPG turbine-powered electrical generator as the prime mover and power source in conjunction with a traction battery. The battery will also provide power for an electro-hydraulic aerial lift and a mobile electric power distribution system when the vehicle is parked. Lastly, the truck will also be capable of supplying emergency power. This project will demonstrate the first plug-in heavy-duty HEV utilizing a microturbine, which is expected to reduce NOx and PM emissions well beyond currently regulated levels. Lastly, if the hybrid system can be developed economically into a kit, this kit will be commercialized by Enova Systems and advocated by EPRI to OEMs for commercialization.

02116: Develop Dual Inductive/Conductive EV Charger Bracket

Contractor: Clean Fuel Connection Inc.	AQMD Cost-share:	$47,815
Subcontractors:	Cosponsors:	
	Trojan	$47,815
Term: 12/31/01 - 03/28/03	Total Cost:	$95,694

There are currently two different types of charging interfaces for electric vehicles: conductive and inductive, which increases the cost of installing public charging sites. This project is for development of an UL-approved bracket that would allow two chargers to be mounted on a single pedestal and footing. In this project, specifications and drawings for the bracket will be developed, a purchase order based on competitive bidding will be placed for prototype brackets, and the prototype brackets will be reviewed by the charger manufacturers and submitted to UL for testing and recognition.

CFM6: Alternative Fuels - Off-Road Applications

02119: Demonstration of Passive Particulate Trap Technologies on Existing Off-Road Heavy-Duty Construction Equipment Fueled by Low-Sulfur Diesel Fuel

Contractor: Booz Allen & Hamilton Inc.	AQMD Cost-share:	$489,143
	Cosponsors:	
	CARB	$400,000

	County Sanitation Districts of LA	$55,000
Term: 12/21/01 - 01/21/03	Total Cost:	$910,000

The contribution of heavy-duty diesel construction equipment to mobile source NOx and PM emissions inventory is projected to increase over other mobile sources in the near future. Particulate traps offer an attractive solution to reduce emissions from existing and new equipment. The proposed demonstration project evaluates emission benefits and durability of passive particulate traps, and assesses the effect of such traps on construction equipment operational performance and structural and mechanical durability. This project could lead to PM emissions reduction of over 80 percent. Johnson Matthey, Engelhard, County Sanitation Districts of Los Angeles County, Sukut Construction, and C. W. Poss provided in-kind contributions to the project.

CFE: Emissions Analysis and Health Effects

01140: Analysis of Exhaust from CNG-Fueled Buses

Contractor: University of West Virginia	AQMD Cost-share:	$48,000
	Cosponsors:	
	NREL	$112,000
	DOE	$150,000
	BP	$23,000
	CARB	$237,000
Term: 05/22/01 – 06/30/02	Total Cost:	$570,000

This project is an addition to a National Renewable Energy Laboratory (NREL), Department of Energy (DOE), BP-Arco (BP) and California Air Resources Board (CARB) sponsored study (EC-Diesel study) to assess the emissions of toxic pollutants from diesel fueled heavy duty vehicles. It provides for analyses of exhausts from CNG fueled transit buses for criteria pollutants, particle size emissions, and for the collection of samples for analysis of toxic pollutants and for the conduct of Ames assays of exhaust extracts from CNG- and diesel-fueled transit buses.

01141: Chemical Analysis of Exhaust Samples from CNG Buses

Contractor: Desert Research Institute	AQMD Cost-share:	$63,543
Term: 05/21/01 – 11/30/01	Total Cost:	$63,543

This project is an addition to a National Renewable Energy Laboratory (NREL), Department of Energy (DOE), BP-Arco (BP) and California Air Resources Board (CARB) sponsored study (EC-Diesel study) to assess the emissions of toxic pollutants from diesel fueled heavy duty vehicles. It provides for chemical analyses of exhaust samples collected from CNG fueled transit buses and for the extraction of particulate and semi-volatile organic samples in preparation for Ames assays of exhaust extracts from CNG- and diesel-fueled transit buses.

01144: Ames Bioassay Analyses on Diesel- and CNG-Fueled Bus Exhaust Samples

Contractor: University of California, Davis	AQMD Cost-share:	$51,979
Term: 09/07/01 - 04/30/02	Total Cost:	$51,979

This project is an addition to a National Renewable Energy Laboratory (NREL), Department of Energy (DOE), BP-Arco (BP) and California Air Resources Board (CARB) sponsored study (EC-Diesel study) to assess the emissions of toxic pollutants from diesel fueled heavy duty vehicles. It provides for analyses of exhaust samples from CNG- and diesel-fueled transit buses using the Ames bioassay for potential genetic toxicity.

01209: Study of Children's Pollutant Exposures During School Bus Commutes

Contractor: University of California Riverside	AQMD Cost-share:	$58,992
	Cosponsors:	
	California Air Resources Board	$450,008
Term: 06/25/01 - 04/30/03	Total Cost:	$509,000

It has been established that children are at risk when traveling by school buses due to exposure to diesel particles and other pollutants. CARB is in the process of initiating a study to characterize the school bus commute exposures experienced by children. This study is intended to focus on diesel buses, with possible extension to natural gas buses as well. Additional testing is needed to study exposure from buses equipped with particulate traps. This study will provide such information from up to 4 buses retrofitted with particulate traps. The project duration is 18 months.

02117: Deployment & Operation of Scanning Mobility Particle Sizers & Low Temperature Tapered Element Oscillating Microbalance in Children Health Study Communities

Contractor: University of Southern California	AQMD Cost-share:	$120,000
	Cosponsors:	
	California Air Resources Board	$74,649
Term: 09/01/01 - 10/31/04	Total Cost:	$194,649

As part of the ARB's Children's Health Study, special particulate monitoring will be conducted at selected monitoring locations in the South Coast Air Basin. This includes Scanning Mobility Particulate Sizers (SMPS) which have the capability to continuously measure nanoparticles. The SMPS units will provide in-depth information about fine particulates which have not been available previously. Such information will be very useful in better understanding the role of particulates in children's health.

02130: Determination of Ammonia and Methane Emissions from Greenwaste Composting

Contractor: Optical Scientific Inc.	AQMD Cost-share:	$50,000
Term: 11/05/01 - 03/30/02	Total Cost:	$50,000

Emission inventory estimates are needed to evaluate potential impact and cost effectiveness of control techniques to reduce emissions from composting. Greenwaste compost does not lend itself to the current measurement technique (EPA Isolation Flux Chamber), due to the coarseness of the greenwaste material and non-uniformity of the piles. In addition, the emissions data are not known until laboratory analyses are conducted and the results reported back. The project is

intended to determine the feasibility of determining ammonia and VOC (methane surrogate) emissions by open-path remote sensing techniques for both the contaminants and wind velocity, avoiding the difficulties associated with the Isolation Flux Chamber technique.

CFO: Other Advanced Technologies

01036: Retrofit School Buses with Particulate Traps

Contractor: Los Angeles Unified School District	AQMD Cost-share:	$15,000
Term: 03/26/01 - 12/15/01	Total Cost:	$15,000

This project will determine the performance characteristics and efficiency of particulate traps manufactured by Engelhard Corporation, for school buses operating on low-sulfur diesel fuel. Emissions measurements will be conducted on representative buses on a chassis dynamometer, at the beginning and at the end of the demonstration program, at CARB's heavy-duty emissions testing facility located at MTA. This project will assist AQMD in crafting strategies to reduce children's exposure to diesel exhaust.

01057: Retrofit School Buses with Particulate Traps

Contractor: Engelhard	AQMD Cost-share:	$72,500
Cosponsor:		
	Engelhard:	$72,500
Term: 09/21/01 – 02/28/02	Total Cost:	$145,000

This project will determine the performance characteristics and efficiency of particulate traps manufactured by Engelhard Corporation, for school buses operating on low-sulfur diesel fuel. Several buses of different ages and engine types will be selected from the Los Angeles, Anaheim, and Hemet Unified school districts' bus fleets. Emissions measurements will be conducted on representative buses on a chassis dynamometer, at the beginning and at the end of the demonstration program, at CARB's heavy-duty emissions testing facility located at MTA. This project will assist AQMD in crafting strategies to reduce children's exposure to diesel exhaust.

01032: Demonstrate School Buses Retrofitted with PM Reduction Technologies

Contractor: Johnson Matthey	AQMD Cost-share:	$89,000
Cosponsors:		
	CARB (in-kind)	$24,000
	Johnson Matthey	$89,000
Term: 12/31/01 - 02/28/021	Total Cost:	$202,000

Johnson Matthey manufactures particulate matter retrofit systems that will be used in school bus demonstration programs in Los Angeles, Anaheim, and Hemet Unified School districts. Johnson Matthey's Continuous Regeneration Trap system (CRT) will be retrofitted in thirteen buses at the participating school districts. The bus matrix will be comprised of six different engine models of both older and newer age categories. All the buses will operate on low-sulfur diesel fuel produced by ARCO, and some of the buses will be tested for exhaust emissions at CARB's heavy-duty testing facility. The performance of the retrofits will be monitored for six months. This project will show which engine makes and model years are most suitable for PM retrofit technologies.

01158: Evaluation of School Bus Retrofit with Exhaust After-Treatment Devices

Contractor: University of California Riverside	AQMD Cost-share:	$49,341
Term: 05/18/01 - 02/14/02	Total Cost:	$49,341

This project will provide assistance to analyze the data and prepare reports regarding the performance characteristics and efficiency of particulate traps for school buses operating on low-sulfur diesel fuel. As part of other projects, emissions measurements will be conducted on representative buses on a chassis dynamometer, at the beginning and at the end of the demonstration program. This project will assist AQMD in crafting strategies to reduce children's exposure to diesel exhaust.

CFT: Technology Transfer and Assessments

02135: Cosponsor Educational Outreach Program

Contractor: SunLine Transit Agency	AQMD Cost-share:	$50,000
	Cosponsors:	
	SunLine	$238,000
	EPA	$100,000
	Various Entities	$160,000
Term: 11/08/01 – 3/31/02	Total Cost:	$548,000

The SunLine Transit Agency will develop and implement an educational outreach program consisting of mobile and stationary exhibits, brochures, classroom workbooks and informative videos regarding alternative fuels and renewable resources. Sunline is a world leader in the use of natural gas transit buses, hydrogen powered vehicles, and solar and other forms of renewable, clean energy sources. The AQMD will provide funding support for these activities and any applicable expertise as needed.

CFS2: Stationary Sources - VOC/PM Reduction Technologies

01172: Assess, Develop and Demonstrate Low-VOC Cleaning Systems

Contractor: Institute for Research And Technical Assistance	AQMD Cost-share:	$149,720
Term: 05/22/01 – 07/31/03	Total Cost:	$149,720

Rule 1171 (Solvent Cleaning Operations) was amended on October 8, 1999 to achieve additional VOC emission reductions by lowering the VOC limits effective December 1, 2001 and July 1, 2005. The technology-forcing VOC limits in 2005 are substantially lower than the VOC content of many of the solvents used today. The October 8, 1999 amendment also requires the Executive Officer to complete a Technology Assessment by July 1, 2004 of low VOC technologies for several cleaning operations to evaluate the feasibility of the future limits. Rule 1171 requires the technology assessment for the cleaning of electrical apparatus and electronic components; and the cleaning of application equipment for coatings, adhesives, screen printing inks, ultraviolet inks, and specialty flexographic printing inks. The objective of this project is to determine if the year 2005 limits for cleaning operations cited above are technologically feasible and cost-effective by an assessment, development, and demonstration of existing and newly developed low-VOC

cleaning systems. If cleaning systems compliant with the year 2005 VOC limits are feasible, approximately 9 tons per day of VOC emissions could be reduced.

PROGRESS IN 2001

Key Projects Completed

A large number of emission sources contribute to the remaining air quality problems in Southern California. Given the diversity of these sources, it is unlikely that a single technology will solve these problems. As a result, the SCAQMD continues to support a wide range of advanced technologies to address this diversity. Projects co-funded by the SCAQMD's Clean Fuels Program have included emission reduction demonstrations for both mobile and stationary sources of air pollution, although legislative amendments and reduced SCAQMD revenues now 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, 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 infrastructures. Stationary source projects have included a wide array of advanced low NO_x technologies, low VOC coatings and processes, and clean energy alternatives, such as fuel cells, solar power, and other renewable energy systems.

Table 4 provides a list of projects completed in 2001. Summaries of these completed projects are included in Appendix C, as available. These summaries describe the progress achieved toward SCAQMD and Clean Fuels Program goals by each completed project.

Selected projects, from the list of projects completed in 2001, representing a range of key technologies from near-term to long-term, are highlighted below.

Natural Gas Engine Electronic Controls for Heavy-duty Vehicles

Natural Gas engines have been demonstrated to be significantly cleaner than diesels for NOx and PM emissions. They also reduce health risks from toxic air contaminants in urban areas. Cummins, a major engine manufacturer, has taken the lead to develop and certify the C8.3G engine (8.3 L Natural Gas engine) to ARB optional low-NOx standard. Electronic controls are the key to emissions performance of such engines throughout the driving cycle.

This project was aimed at developing the electronic controls for this particular engine, and demonstrating it in a heavy-duty vehicle. SCAQMD contributed $265,000 to this project with a total cost of $602,550. The electronic engine management system was developed, verified, and launched into production. One field system was placed at a Sunline Transit bus and showed good performance and durability. FTP cycle test results showed very low NOx emissions of 1.53 g/bhp-hr and PM emissions of 0.008 g/bhp-hr.

This product development has successfully entered into commercialization. The C8.3G family of engines has been in production for sometime, particularly serving the market for alternative-fuel refuse and recycling trucks. The clear benefits of this project includes (1) lower emissions; (2) more reliable engine controls; and (3) wider range of natural gas fuel for increased market penetration of this engine.

Zero Emissions Technologies for Lawn and Garden Equipment

Electric lawn and garden equipment reduce noise and emissions from conventionally fueled mowers and portable gardening equipment. Zinc/Air fuel cell technologies are an alternative to lead-acid batteries currently used for powering electric lawn and garden equipment. Zinc/air fuel cells have zero emissions and can provide the required range and can be refueled easily. Hence they overcome a key barrier to commercial acceptance of zero emissions lawn and garden equipment.

This project was aimed at converting a commercial electric green mower provided by the Toro Company to zinc/air fuel cell technology, and produce a portable power source with the same technology to power a leaf blower and similar garden equipment. SCAQMD provided $350,000 while the total project cost, after completion, was determined to be little over $1 million.

The fuel cell powered greens mower demonstrated a total 5.7 kWh of available energy capacity, giving on the average about 3.2 hours of service time between refueling. It was repeatedly filled with new electrolyte and zinc in about 15 minutes easily. Further development work, however, is needed to reduce the weight and mange parasitic losses. The portable power source was demonstrated by a Toro leaf blower and a Black & Decker hedge trimmer.

The project successfully demonstrated the world's first prototype zinc-air fuel cell powered lawn mower and portable garden equipment. The manufacturer, Metallic Power, is working on lowering cost and optimizing specific energy (energy per unit weight) for a commercial introduction of this type of equipment.

On-Road Emissions Measurement Systems for Heavy-Duty Trucks

Emissions from heavy-duty diesel engines are certified on engine dynamometers using test cycles that are intended to replicate "real world" operating scenarios. However, they rarely represent actual operating conditions. The College of Engineering – Center for Environmental Research and Technology (CE-CERT) at the University of California, Riverside (UCR) has developed and constructed a world-class laboratory which consists of a full complement of emissions measurement instrumentation contained in a 53-foot trailer. The laboratory itself serves as the load for the truck, which pulls the trailer where the emissions are captured and measured.

The SCAQMD contributed $150,000 to this $991,000 project, in partnership with U.S. EPA, Detroit Diesel Corp., Caterpillar Inc., Cummins Engine Co., Volvo Truck Corp., Mack Truck Inc., and Navistar International Transport Corp. The Laboratory construction was completed in 2000 and the unit is now operational for data acquisition. Research plans include studies of the effectiveness of diesel fuel reformulation, after-treatment technologies, alternative fuels, alternative powertrains and hybrid engines, in reducing emissions. While designed for mobile source applications, the unit can also be used to study emissions from stationary sources such as power generating equipment.

These studies will provide information on "real world" emissions benefits of various strategies and technologies that may be helpful in designing control strategies and assessing emission inventories.

Table 4. Projects Completed Between January 1 and December 31, 2001

CONTRACT	CONTRACTOR	PROJECT TITLE	DATE
CFM2: Alternative Fuels - On -Road Applications			
00091	Cummins Engine Co Inc	Development & Demonstration of Advanced Natural Gas Engine Electronic Controls	Nov-01
01031	USA Pro & Associates	Establishment of Design Practices for CNG Trucks & Requirements of the Use of Methane Detection on NG Trucks	May-01
99157	Clean Air Partners	On-Road Development of Enhanced Caterpillar C-12 Dual-Fuel Truck Engine	Oct-01
01166	Los Angeles Unified School District	Evaluate Durability of PM Retrofit Trap on a School Bus	Dec-01*
CFM3: Alternative Fuels - Infrastructure			
01179	Arthur D. Little Inc.	Cosponsor Clean Fuel Infrastructure and Demographic Study	Dec-01
CFM4: Fuel Cell and Hydrogen Technologies			
96116	Small-Scale Fuel Cell Commercialization Group Inc.	Prototype Residential Fuel Cell Systems	Aug-01
99135	California State Polytechnic University Pomona	Develop an Improved Electrode for Direct Methanol Fuel Cell Using Magnetron Sputtering Techniques	Sep-01
00029	Xcellsis	Methanol Fuel Quality Specification Study	Jun-01
01047	California Institute of Technology	Complete Development of Direct Methanol Fuel Cell	Aug-01
CFM5: Electric and Hybrid Electric Technologies			
01023	CALSTART	Study of Electric Hotel Shuttle Service at LAX	Oct-01
CFM6: Alternative Fuels - Off-Road Applications			
99067	Metallic Power Inc.	Zinc/Air Battery-Powered Commercial Grounds Care Equipment	Jun-01
CFE: Emissions Analysis and Health Effects			
97122	California Air Resources Board	Heavy-Duty Vehicle Fleet Characterization for NOx & PM Emissions	May-01
98114	University of California Riverside	Analysis of the Effectiveness of On-Board Diagnostics II	Mar-01
99045	California Air Resources Board	Fast-Response On-Board NOx Sensors for Heavy-Duty Vehicles	Jun-01
99120	University of California Riverside	Evaluation of the Effects of Biodiesel & Other Clean Fuel Blends on Exhaust Emission Rates & Reactivity Phase 2	Apr-01

* Since this contract was one of several projects comprising a particulate trap study ending in 2002; this contract will be incorporated into a final report encompassing all the particulate trap projects in the next annual report.

Table 4. Projects Completed Between January 1, 2001 and December 31, 2001

CONTRACT	CONTRACTOR	PROJECT TITLE	DATE
CFE: Emissions Analysis and Health Effects (cont'd)			
99128	University of California Riverside	Develop On-Road System for Emissions Measurement for Heavy-Duty Trucks	Jan-01
99131	University of California Riverside	Investigate Emission Rates of Ammonia & Other Toxic & Low-Level Compounds Using FTIR	Feb-01
CFO: Other Advanced Technologies			
01036	Los Angeles Unified School District	Demonstration of School Buses Retrofitted with PM ReductionTechnologies	*Dec-01
CFS1: Stationary Sources - Clean Energy Technologies			
97130	Clemson University Research Foundation	Advanced Premixer/Catalytic Combustor for Natural Gas Turbines	Jul-01
CFS2: Stationary Sources - VOC and PM Reduction Technologies			
99143	AVES	Zero- & Low-VOC Resin Technology for Advance Control Measure Development	Mar-01
CFT: Technology Transfer and Assessments			
97125†	AC Propulsion Inc.	Technical Support & Maintenance for AQMD EV Fleet	Aug-01
98150†	University of California Irvine	Support the National Fuel Cell Research Center	Jun-01
99134	California State University Los Angeles	Cosponsor Solar Eagle III Visitation Program	Sep-01
00073†	Vanderborgh, Nicholas	Letter Agreement for Clean Fuels Advisory Group Members	Feb-01
00074†	Runkel, Brian	Letter Agreement for Clean Fuels Advisory Group	Feb-01
00075†	Roan, Vernon	Letter Agreement for Clean Fuels Advisory Group Members	Feb-01
00076†	Kalhammer, Fritz	Letter Agreement for Clean Fuels Advisory Group Members	Feb-01
00077†	Union of Concerned Scientists	Letter Agreement for Clean Fuels Advisory Group Members	Feb-01
00154†	California Science Center Foundation	Design Interactive Fuel Cell Museum Exhibit	Aug-01
00169†	University High School	Cosponsor Solar Electric Car Program	Nov-01
00194	City of Claremont Police Department	Battery-Operated Emergency Roadside Flares	Aug-01
01021†	GE Energy & Environmental Research Corporation	Technical Assistance Pertaining to Adv Combustion Systems & Stationary Source NOx Control Technologies	Aug-01
01033†	University of California Davis	Cosponsor Fuel Cell Vehicle Center	Dec-01

Table 4. Projects Completed Between January 1, 2001 and December 31, 2001

CONTRACT	CONTRACTOR	PROJECT TITLE	DATE
CFT: Technology Transfer and Assessments (cont'd)			
01063†	Gladstein & Associates	Assist with Conference and Cosponsor Symposium	Mar-01
01076†	Information Television Network	Cosponsor Documentary on The Clean Air Act	May-01
01091†	Coordinating Research Council Inc	Cosponsor the 11th CRC Emissions Workshop	Sep-01
01090†	Los Angeles Municipal Art Gallery	Smog Catcher Project	Dec-01
01108†	Riverside Municipal Museum	Implement Children's AQ Initiative	Jun-01
01110†	National Hydrogen Association	Cosponsor 12th Annual US Hydrogen Meeting	Sep-01
01112†	WestStart-CALSTART	Cosponsor Clean Heavy-Duty Vehicles for the 21st Century Conference	Oct-01
01113†	Western Riverside Council of Governments	Cosponsor 3rd Annual Clean Cities Event	Apr-01
01114†	TRED Foundation	Cosponsor 3rd Bi-Annual World Truck Conference	Oct-01
01182†	WestStart-CALSTART	Cosponsor the Bus Rapid Transit National Competition	Jun-01
01191†	SAE International	Cosponsor the SAE 2001 Future Transportation Technology Conference	Dec-01
01218	Los Altos High School	Cosponsor American Solar Challenge	Sep-01
01221†	College of the Desert on Behalf of ATTI	Staff Training on CNG Maintenance and Inspections	Sep-01
02052†	Air Products and Chemicals Inc.	Participation in NG-H2 Compatibility Study Team	Oct-01
02053†	Zoellick, Jim	Participation in NG-H2 Compatibility Study Team	Oct-01
02054†	Lehman, Peter	Participation in NG-H2 Compatibility Study	Oct-01
02068†	Center for Hydrogen Safety, LLC	Consulting Services for Hydrogen Codes and Standards	Nov-01
02144†	Institute of Ecolonomics	Cosponsor The Drive For Life	Dec-01

*Project Summary not available at the time of printing this document.
†Project summary is not needed for AQMD-sponsored events and technical assistance.

FUTURE TECHNOLOGIES

Funding Priorities for 2002

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-art. 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 Air Quality Management Plan (AQMP) for the South Coast Air 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 2010, 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.

Technology-based mobile source control measures in the 1997 AQMP address heavy-duty on-road vehicles, light-duty on-road vehicles, and off-road equipment.

- Measures M4, M5, and M6 reference a heavy-duty engine NO_x emission standard of 2.0 g/bhp-hr, to be implemented between 1997 and 2002. The cost effectiveness projected for these measures is \$3,120 – 8,990/ton of NO_x removed. Estimated emission reductions from these measures are projected to be about 62 tons NO_x/day. Since 1997, significant progress has been made in the development and commercialization of heavy-duty alternative fuel engines that meet that standard. The Moyer Program, as implemented by the SCAQMD, demonstrates that there is considerable demand for these engines if they are cost competitive and that the cost effectiveness of these technologies for emission reductions is reasonable. More recently, the ARB has identified heavy-duty engines for further regulation and reduction in standards, targeting NO_x emissions of 0.5 g/bhp-hr in 2004 and 0.2 g/bhp-hr in 2007.

- Measure ATT-03 references zero emission light-duty vehicles and related infrastructure to be implemented between 1997 and 2010. The major automobile manufacturers have introduced a limited number of electric vehicles into the marketplace with what can best be characterized as mixed commercial success. Key challenges for electric vehicles to gain greater market share include first costs, limited range, and limited, although growing, recharging infrastructure. Advanced batteries that provide extended range and that may allow some cost reduction appear needed. A promising zero emission technology being actively pursued by automobile makers is fuel cell technology. Although automobile makers have announced intentions to introduce fuel cell vehicles in the 2004-05 timeframe, key challenges that remain are the cost of the fuel cells and the infrastructure to refuel early introduction fuel cell vehicles, likely to be fueled by hydrogen or methanol.

- Off-road vehicles and equipment are targeted by several AQMP control measures. Measures M9 and M10 target off-road diesel equipment with a proposed NO_x standard of 2.5 g/bhp-hr by 2005. The estimated benefit is a 46 tons/day reduction in NO_x emissions. Industrial

equipment, such as forklifts, fueled by gasoline and propane are targeted by measures M11 and M12 for control by three-way catalysts, a transfer of successful automotive technology, by 2000-04. Expected emission reductions for M11 and M12 are NOx (17 tons/day), VOC (32 tons/day), and CO (1038 tons/day).

- Off-road equipment under the jurisdiction of the US Environmental Protection Agency is also targeted in the 1997 AQMP as requiring controls. Measure M13 targets marine vessel for control in 1998-2001 for 30 percent reduction in NO_x for a projected benefit of 15 tons/day. Locomotives are targeted in M14 for a 67 percent NO_x reduction in 2000-10, which should provide a reduction of 17 tons/day. Aircraft are targeted for 30 percent reduction of VOC and NO_x by measure M15, which is expected to reduce VOC by 3 tons/day and NO_x by 5 tons/day.

The primary challenges with respect to stationary sources are related to VOC emissions, in large part to the relatively small contribution stationary sources make to the NO_x inventory. The 1997 AQMP identifies several long-term measures to reduce VOC emissions from a number of applications in the 2006-10 timeframe, including:

- Consumer products - 43 tons/day
- Architectural coatings – 20 tons/day
- Solvent cleaning and degreasing – 19 tons/day
- Industrial coating and solvent use – 20 tons/day
- Fugitive emission – 18 tons/day
- Industrial process operations – 8 tons/day

In addition to 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 so-called "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 Air Basin. This Technology Advancement Plan 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 exist a range of projects that represent near-term to long-term efforts. With respect to timeframes, all future projects are expected to begin in 2002 with the time-to-product dependent on the technology maturity and market forces. The SCAQMD Clean Fuels Program tends to support development, demonstration, and technology commercialization efforts, but not fundamental research. The general time-to-product for those efforts, from long-term to near-term, are described below:

- Technology development projects included in this plan are to begin during 2002 with expected completion in about two years. Additional field demonstrations to gain long-term verification of performance, spanning up to two years, may 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 2007. 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 2009 or later.

- More mature technologies, that is, those ready to begin field demonstration in 2002, are expected to result in a commercial product in 2004-05. 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 also help alleviate future purchasers of concerns with being the first user "guinea pig" by providing real-world evidence of a technology's performance.

- Commercialization-ready technologies, that is, those that have been successfully developed, demonstrated, and certified, are included in this plan through incentive programs established to offset higher first costs due to their as yet limited production. The incentive programs are needed to encourage use of the cleanest technologies sooner rather than later, and establish an early market penetration that would provide manufacturers justification to gear up for mass production that would ultimately reduce the costs of these new technologies.

Summary of Technical Priorities

The SCAQMD program maintains flexibility to address dynamically evolving technologies and the latest progress in the state-of-art. The challenge for SCAQMD is identification of programs in which the available funding can make a difference. Major technical program areas are identified below and specific project categories are discussed in more detail.

Not all project areas will be funded, given the funding constraints and the availability of suitable projects. The top priority 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.

Incentive Programs

Incentive programs encourage the immediate use of commercially available, low emission heavy-duty and off-road alternative fuel engines to replace high-polluting diesel engines and to reduce the resulting toxic exposures. The SCAQMD Governing Board has committed to provide $3.5 million from the Clean Fuels Fund to meet the legislatively mandated local matching fund requirement for the Carl Moyer Program solicitation. An additional $531,000 has been identified to provide financial incentives to school districts to purchase clean fuel school buses. Participation in ARB ZEV Incentive Program does not require matching funds; however additional local funds may be instrumental in placing these vehicles within SCAQMD.

The incentive programs are needed to encourage use of the cleanest technologies sooner rather than later, and establish an early market penetration that would provide manufacturers justification to gear up for mass production. It is important to note that these matching funds from the Clean Fuels Program serve to assist in commercialization of alternate fuel vehicles, which is a goal of the SCAQMD Clean Fuels Program.

Fuel Cells Vehicles and Hydrogen

Fuel cells are emerging as a leading alternative technology to power ZEVs and near-ZEVs. In theory, fuel cell vehicles are hybrid electric vehicles that may be powered by different types of fuel cells and different fuels. It appears now that PEM fuel cells and compressed hydrogen will power the first fuel cell vehicles. For the future, there remains uncertainty with respect to fuel choice and, thus, infrastructure requirements. Even for hydrogen, there are several pathways or

means of producing and storing the fuel in both on-board and off-board applications. Considerable research, development and demonstration efforts are already underway to address these issues by some of the largest automobile manufacturers and fuel suppliers of the world. Yet much work is needed to improve the performance and range of these vehicles, bring down the cost, develop a viable fueling infrastructure, and obtain public acceptance for a brand new technology in everyday application.

Most major car manufacturers have announced their intent for commercial introduction of fuel cell vehicles by the 2004-2006 timeframe. The objective of the California Fuel Cell Partnership, established in April 1999, is to demonstrate fuel cell vehicles and facilitate their commercialization. A recent study released by the Partnership has highlighted the issues with fuel choice for both near term and the future. The 2002 Plan Update identifies key opportunities consistent with the Partnership and for applications beyond the Partnership, to develop needed hydrogen refueling and storage technologies, and expand applications of fuel cell cars and buses among suitable fleet operators. Specifically, future projects are expected to include:

- Demonstration of Fuel Cell Vehicles in controlled fleet applications in the Basin.
- Development of specifications for Fuel Cell Transit Buses.
- Development and demonstration of distributed hydrogen production and refueling stations.
- Certification of hydrogen personnel and hydrogen components and subsystems.
- Improvements of existing fuel cell technologies.

On-Road Technologies

The use of alternative fuels can provide significant reductions in NO_x and PM emissions. The replacement and further control of heavy-duty on-road diesel engine emissions in the near future is an important area for the 2002 Plan Update. 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. Existing diesel emissions can be reduced with after-controls such as Particulate Matter Traps (P-Traps) and catalysts, as well as lowering the sulfur content or using additives with diesel fuel. Hybrid electric technologies and the use of microturbines instead of internal combustion engines have also shown promise for replacing higher polluting diesel engines. Gas-to-Liquid (GTL) fuels, formed from natural gas or other gas rather than petroleum feedstock, provide low-emission fuels for use in diesel engines. All of these options are worth pursuing for cleaner engine technologies and immediate emission reductions.

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:

- Development of heavy-duty alternative fuel engines to achieve NO_x emissions of 0.5 g/bhp-hr and PM emissions of 0.01 g/bhp-hr.
- Demonstration and certification to low emission standards of higher horsepower alternative fuel heavy-duty vehicles, including hydrogen-natural gas blends.
- Development of alternative-fuel school buses of various sizes.
- Advanced on-board gaseous fuel storage technology development.

- Demonstration of zero-emission technology for idling heavy-duty trucks and trailers.
- Next Generation Natural Gas Vehicle development and deployment.
- Evaluation and demonstration of new emerging liquid fuels, including ultra-low sulfur diesel and Fischer-Tropsch fuels.

Infrastructure

The importance of refueling infrastructure cannot be overemphasized for the realization of alternative fuel technologies on the road. Significant demonstration and commercialization efforts are underway to support the deployment of electric vehicles, natural gas vehicles, hybrid vehicles and future fuel cell vehicles. SCAQMD fleet rules already require certain types of fleets to purchase and operate clean fuel vehicles in the Basin, and many types of vehicles are being introduced in response. Electric charging stations and CNG and LNG refueling stations are being positioned to support these fleet and private applications today. For the future, it is expected that a small number of compressed hydrogen fueling stations will be initially needed in the Basin for the early fleet of fuel cell vehicles by the middle of this decade.

Besides technology, some of the 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 to be developed for infrastructure development include:

- Development and demonstration of advanced, cost effective CNG and LNG stations.
- Development of LNG detection technologies.
- Demonstration of natural gas refueling stations capable of refueling hydrogen fuel cell vehicles.
- Development of standards, certifications and codes for new clean fuels.
- Investigation of small-scale LNG manufacturing and distribution technologies.

Electric and Hybrid Electric Technologies

Significant emission reductions are possible by the use of battery electric and hybrid electric technologies in both light-duty and heavy-duty applications as well as off-road equipment. Investment in internal research and development of electric and hybrid electric vehicles by major vehicle manufacturers, supplemented with significant investment by the federal government, dwarfs the budget available to the SCAQMD. 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 only, and can be coupled with natural gas engines, microturbines, and fuel cells for further emission benefits in future.

While battery electric vehicles offer the most environmental benefits, issues with cost and vehicle range, which depend on further advancement of battery technology and battery management, still cloud their public acceptance. However, there are a number of opportunities to develop and demonstrate technologies that could enable expedited widespread use of electric vehicles and hybrid electric vehicles in the Basin, including:

- Demonstration of advanced energy storage technologies, including ultra-capacitors.

- Development and demonstration of fast and innovative charging systems for power storage for electric or hybrid electric vehicles.
- Development of innovative battery electric vehicle applications.
- Evaluation and demonstration of light and medium-duty hybrid electric vehicle systems.
- Demonstration of heavy-duty hybrid electric vehicles.
- Upgrade and demonstration of hybrid electric buses.

Off-Road Technologies

Off-road equipment such as heavy-duty construction equipment, locomotives, and marine engines are typically diesel-powered. In many instances, off-road equipment are powered by engines also used in on-road vehicles. Since off-road mobile sources are regulated and controlled to a significantly lesser degree than on-road vehicles, there appears to be an opportunity to transfer technologies proven in on-road applications to off-road equipment. Almost all of the technologies discussed under on-road applications, including P-traps, diesel fuel reformulation, natural gas engines, GTL fuels, and hybrid electric technologies can find applications to off-road equipment. Specifically, future projects are expected to include:

- Demonstration of Low- and Zero-Emission locomotives using LNG and hybrid electric technologies. For the longer term, fuel cells may be an ideal powerplant for locomotives.
- Development and demonstration of clean alternative fuel engines for off-road applications.
- Multi-year demonstration of advanced alternative diesel fuels, such as Gas-to-Liquid fuels and/or after-treatment technologies to heavy-duty off-road equipment.
- Demonstration of alternative fuel technologies in marine applications.

Stationary Sources

Although progress is being made in the development and commercialization of zero-VOC products and processes, further technology advancements are needed to achieve AQMP goals. Solvents and coatings research is continuing to find cleaner replacements for higher-VOC products. The threat of diesel backup generators prompted by the recent power crisis has again focused attention on cleaner distributed power generation options such as natural gas microturbines, fuel cells, and hybrid technologies which produce low or no emissions of NOx and PM. The ARB has also recently adopted standards for such distributed generation equipment for the first time.

Future technology priorities will focus on "pollution prevention" technologies, which appears to be the most promising approach for this diverse source category, including:

- Development and Demonstration of Near-Zero or Zero-VOC products for various applications in the Basin.
- Evaluation, Development, and Demonstration of Advanced VOC Control Technologies for Miscellaneous Stationary Sources.
- Technology Assessments of Future VOC Limits in Current Source Specific VOC Rules.
- Demonstration Project for Portable NG/LPG-Powered Microturbine Generators.

- Demonstration of Hybrid Fuel Cell/Microturbine Generators Fueled by Natural Gas or Propane.
- Development and Demonstration of Low-Emission Refinery Flares.
- Development and Demonstration of Low-Emission Emulsified Diesel Fuel Technology for Portable Power Generators.

1.5 Target Project Allocations

Figure 4 presents the potential allocation of available funding, based on SCAQMD projected program cost of $27 million for all potential projects. The expected actual project expenditures for 2002 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 2002 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.

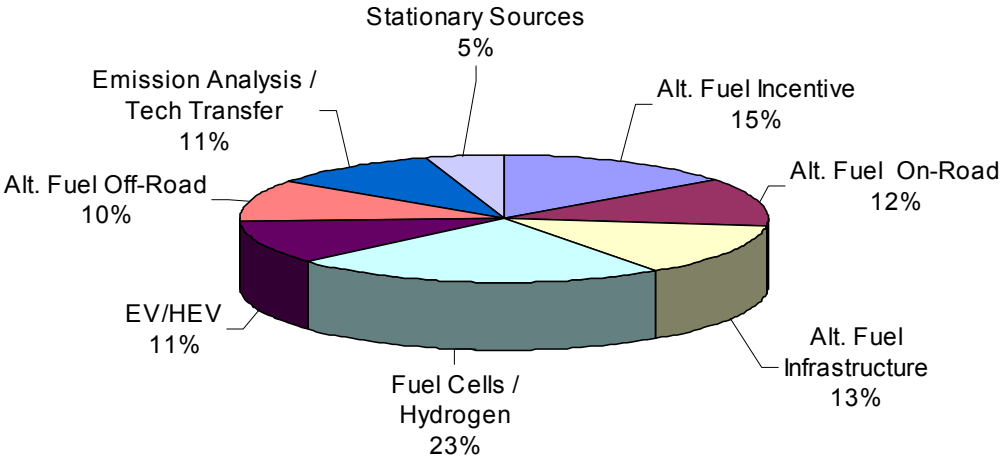


Fig. 4: Projected Cost Distribution for Potential SCAQMD Projects in 2002 ($27 million)

APPENDIX A

Technology Advancement Advisory Group

California Air Resources Board	Tom Cackette
California Energy Commission	Nancy Deller
Clean Air Now	Philip J. Hodgetts
Coalition for Clean Air	Tim Carmichael
GE Energy and Environmental Research Corp.	Blair Folsom, Ph.D.
L Monty Body Shop	Dan Moran
Rancho Los Amigos Hospital	Henry Gong, M.D.
Sempra Energy	Robert Nicksin
Small Business Coalition	John D. Harper, Jr.
Southern California Edison	William R. West
Terra Furniture	Gary Stafford
U.S. Department of Energy	Robert S. Kirk, Ph.D.
U.S. Department of Transportation	Shang Hsiung
Western States Petroleum Association	John Freel
Westway Terminals	Michael La Cavera

SB 98 Clean Fuels Advisory Group

Todd Campbell	Coalition for Clean Air
Dr. Blair Folsom	GE Energy and Environmental Research Corporation
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	Union of Concerned Scientists
Dr. Melanie Marty	Office of Environmental Health Hazard Assessment
Dr. Joseph Norbeck	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	Blue Star Industries Corporation
Michael Walsh	Independent Consultant in Motor Vehicle Pollution Control

APPENDIX B

Open Clean Fuels Contracts as of January 1, 2002

Contract	Contractor	Project Title	Start Term	End Term	AQMD $	Project Total $

CFM1: Alternative Fuels - Incentive Programs

01051	Fabrica Int'l.	Purchase 2 Electric Forklifts w/ Batteries	10/11/01	12/31/05	$25,598	$25,598
01104	Seaworthy Systems, Inc.	Evaluate Carl Moyer Marine Vessel Proposals	01/19/01	01/31/02	$50,000	$50,000
01137	R.F. Dickson Company, Inc.	Repower 10 & Purchase 4 PM10-efficient CNG Street Sweepers	04/17/01	12/31/06	$1,010,000	$1,010,000
01138	Hayward Pool Products, Inc.	Purchase 2 Electric Forklifts w/ Batteries	05/02/01	06/15/06	$20,200	$20,200
01151	Virco Manufacturing	Purchase 30 Electric Forklifts with 2 Battery Packs	12/31/01	12/31/07	$424,190	$424,190
01160	Waste Management of the Desert	Repower 7 Roll-off Refuse Trucks LNG	10/03/01	06/30/08	$526,547	$1,053,094
01162	Arthur D. Little Inc	Technical & Management Assistance for Carl Moyer & School Bus Programs	04/20/01	04/19/03	$150,000	$150,000
01165	Pickens Fuel Corp	Construct & Operate 1 LNG & 4 CNG Fueling Stations within SCAQMD Basin	05/07/01	03/30/06	$788,800	$1,577,600
01169	Clean Fuels Connection Inc.	Technical and Management Assistance for Carl Moyer School Bus and ZEV Implementation Programs and Infrastructure Scoping	04/20/01	04/19/02	$225,000	$225,000
01178	CalMet Services, Inc.	Repower 27 Waste Collection Trucks w/ CNG	09/19/01	06/30/07	$1,323,000	$2,646,000
01336	Chroma Systems	Purchase Electric Forklift w/ Battery	04/11/01	06/30/06	$4,734	$4,734
00105	Avery-Dennison Office Products North America	Purchase 9 Electric Forklifts	06/20/00	03/15/06	$10,000	$277,452
00107	Harbor Distributing, LLC	Purchase 32 Electric Forklifts	05/16/00	03/15/06	$430,400	$1,847,464
00113	Lowes Home Improvement Warehouse Inc	Purchase 40 Electric Forklifts	05/24/00	03/15/06	$560,000	$1,843,190
00131	HomeBase Inc	Purchase 20 Forklifts	06/07/00	03/15/06	$412,000	$1,400,000

CFM2: Alternative Fuels - On-Road Applications

00114	Alta Loma School District	Purchase 2 CNG School Buses	03/22/00	06/01/05	$119,608	$464,000
00116	Montebello Unified School District	Purchase 2 CNG School Buses	06/07/00	06/01/05	$119,608	$464,000
00193	Transportation Foundation of Los Angeles	Evaluation of Alternative Fuel Transit Bus Maintenance Practices and Design of Training Curriculum for Maintenance & Repair of Alternative Fuel Transit Buses	08/23/00	02/15/02	$200,000	$250,000
01035	Baytech Corporation	Develop Ultra Low Emission Natural Gas Vehicle for Use in Shuttle and Package Delivery Applications	12/18/00	04/15/02	$186,211	$398,729
01173	National Renewable Energy Laboratory	Demonstration of Fischer Tropsch Synthetic Fuel in Heavy & Medium-Duty Vehicles; Advanced Diesel Fuels, Engines, Nox Absorber Catalyst & Diesel Particulate Filter Project	06/11/01	07/31/03	$378,001	$2,248,001
01225	Detroit Diesel Corporation	Development of Very Low-NOx Heavy-Duty Natural Gas Engine	04/20/01	05/30/03	$1,530,966	$3,458,150
99121	University of Southern California	Demonstrate Reduced Vehicular Emissions Through Throttleless Engines Using Alt Fuels	06/02/99	08/03/02	$85,300	$193,800

Contract	Contractor	Project Title	Start Term	End Term	AQMD $	Project Total $

CFM2: Alternative Fuels - On-Road Applications (cont'd)

99158	Gas Research Institute	Development & Demonstration MACK E7G Natural Gas Engine @ 400 HP	06/30/99	12/01/02	$400,000	$2,881,705

CFM3: Alternative Fuels - Infrastructure

99118	Ocean Air Environmental, LLC	Advance Fast-Fill Natural Gas Compressor to Refuel Natural Gas Vehicles	05/17/99	09/15/02	$200,000	$592,000
99160	California Energy Commission	Demonstrate Small-Scale Natural Gas Liquefaction Plant	06/09/99	12/31/02	$200,000	$500,000
00071	IMPCO Technologies Inc	Development and Demonstration of an Advanced High Capacity, High Performance NGV Storage Tank	02/22/00	01/31/02	$320,000	$1,420,000
00139	Gas Research Inst	Development & Demonstration of Advanced Safety Inspection Methods for NGV Tanks	07/21/00	12/31/02	$325,000	$2,303,000
01095	Hydrogen Burner Technology Inc.	Demonstration of a Hydrogen Refueling Station	02/16/01	09/15/03	$300,000	$920,000
01152	Pickens Fuel Corp	Construction Mgmt and Consulting Services for NG Fueling Station and AQMD Headquarters	03/16/01	04/30/02	$26,415	$26,415
01154	R.F. Dickson Company, Inc.	Cost-share Installation of CNG Fueling Facility	08/04/01	07/31/06	$180,000	$180,000
01190	USA PRO	Technical and Management Assistance for Infrastructure	06/04/01	06/03/03	$100,000	$100,000
02029	Pickens Fuel Corp	Development and Demonstration of a Universal Card Reader System	12/31/01	05/31/02	$30,000	$65,000
02080	FuelMaker Corporation	Development and Demonstration of Advanced Home Refueling Appliance for CNG Vehicles	11/08/01	06/30/02	$500,000	$1,225,000
02127	Pinnacle CNG Systems LLC	Construction of Fast-Fill CNG Fueling Station at AQMD Headquarters	12/31/01	06/30/02	$395,640	$565,000

CFM4: Fuel Cell and Hydrogen Technologies

97108	Los Angeles County Metropoliltan Transportation Authority	Modeling, Design, & Demonstration of a Fuel Cell Power System for the ATTB Bus	06/11/97	08/31/02	$350,000	$2,136,000
98091	Honeywell	Fuel-Flexible Proton Exchange Membrane Fuel Cell Power System for Vehicle Applications	06/01/98	03/31/02	$500,000	$9,000,000
99064	Hydrogen Burner Technology Inc.	Thermal Partial Oxidation Unit to Reform Methanol Fuel & Simulated Landfill Gas	03/19/99	01/15/02	$200,000	$469,500
00053	Southern California Edison Company	Development & Demonstration of a 250kW Hybrid Fuel Cell-Micro Turbine Powerplant	07/18/00	10/30/02	$200,000	$16,200,000
00135	SunLine Services Group, Inc.	Relocate Hydrogen Facility	05/31/00	05/15/02	$55,000	$325,000
02136	University of California Irvine	Renew Participation For 3 Years in National Fuel Cell Research Ctr at UCI	11/08/01	10/31/04	$90,000	$1,250,000

Contract	Contractor	Project Title	Start Term	End Term	AQMD $	Project Total $

CFM5: Electric and Hybrid Electric Technologies

99068	Air Resources Board	Establish Electric Vehicle Loan Program for Government Agencies/$250k EPA	11/01/98	05/31/02	$80,000	$640,000
99109	Toyota Motor Co.	Three Year Lease of One RAV4 EV	04/04/99	11/30/02	$46,307	$46,307
00020	EV Rental Cars	Demonstration of Electric Vehicle Rental Program	09/08/99	06/30/03	$200,000	$1,175,755
00051	Santa Barbara Electric Bus Works Inc	Develop & Demonstrate an Electric School Bus	11/23/99	03/31/02	$100,000	$400,000
00143	Los Angeles Department of Water and Power	Purchase 25 Electric Buses	06/28/00	06/01/05	$450,000	$5,511,944
00164	Electric Power Research Institute	Evaluate Hybrid Electric Vehicles	06/01/01	02/28/02	$50,000	$140,000
00170	Southern California Gas Company	Demonstrate an Increased Horsepower Natural Gas Engine in On-Road Delivery Trucks	10/20/00	03/01/02	$105,800	$292,200
00192	Southern California Edison Co.	Demonstration & Evaluation of U.S. Postal Service Electric Mail Delivery Vehicles	07/28/00	03/31/02	$399,617	$23,534,617
01022	University of California Davis	Development & Evaluation of Battery Dominant Hybrid Electric Vehicle Systems	04/11/01	09/30/02	$400,000	$3,651,000
01111	Trojan Battery Company	Demonstration & Demonstration of Commercial Prototype Adv. Valve Regulated Lead-Acid Batteries	02/22/01	02/28/03	$150,000	$391,000
01208	Southern California Edison Co.	Development & Demonstration of Grid-Rechargeable Hybrid-Electric Utility Service Truck & Mobile Electric Power Supply	08/10/01	05/01/02	$266,348	$532,695
02116	Clean Fuels Connection Inc.	Development of Dual Inductive/Conductive Charger Bracket to Allow Reduction of EV Charging Infrastructure Costs	12/31/01	03/28/03	$47,815	$95,694

CFM6: Alternative Fuels - Off-Road Applications

02119	Booz Allen & Hamilton Inc.	Demonstration of Particulate Trap Technologies	12/21/01	01/21/03		$910,000

CFE: Emissions Analysis and Health Effects

96081	Public Health Foundation (California Public Health Foundation)	Health Effects of PM10 in the Coachella Valley	01/16/96	02/10/02	$204,186	$297,726
99038	Coordinating Research Council Inc	Evaluate Diesel Particulate Sampling Methodology & Determine Zone of Influence of Ultrafine Particle Fraction of On-Road Emissions	11/10/98	04/30/02	$100,000	$1,509,752
99099	Rancho Los Amigos Research & Education Inst Inc	Evaluate Health Impacts of Multipule Toxic Air Pollutants in a Community	04/04/99	09/25/02	$129,878	$329,069
00188	University of California Riverside	Testing Support & Emissions Assessment	07/17/00	07/01/02	$100,000	$100,000
01140	West Virginia University	Analysis of Exhaust from CNG-fueled Buses	05/22/01	06/30/02	$48,000	$570,000
01141	Desert Research Institute	Chemical Analysis of Exhaust Samples from CNG Buses	05/21/01	02/28/02	$63,543	$63,543
01144	University of California Davis	Ames Bioassay Analyses on Diesel- and CNG-Fueled Bus Exhaust Samples	09/07/01	04/30/02	$51,979	$51,979
01209	University of California Riverside	Study of Children's Pollutant Exposures During School Bus Commutes	06/25/01	04/30/03	$58,992	$509,000

Contract	Contractor	Project Title	Start Term	End Term	AQMD $	Project Total $

CFE: Emissions Analysis and Health Effects (cont'd)

02117	University of Southern California	Deployment & Operation of Scanning Mobility Particle Sizers & Low Temperature Tapered Element Oscillating Microbalance in Children Health Study Communities	09/01/01	10/31/04	$120,000	$194,649
02130	Optical Scientific Inc.	Determination of Ammonia and Methane Emissions from Greenwaste Composting	11/05/01	03/30/02	$50,000	$50,000

CFO: Other Advanced Technologies

01032	Johnson Matthey	Demonstrate School Buses Retrofitted with PM Reduction Technologies	12/31/01	02/28/02	$89,000	$202,000
01048	Hemet Unified School District	Demonstrate School Buses Retrofitted with PM Reduction Technologies	10/20/00	02/28/02	$10,000	$543,200
01057	Engelhard Corp	Demonstration of School Buses Retrofitted with PM Reduction Technologies	09/21/01	02/28/02	$72,500	$145,000
01158	University of California Riverside	Evaluation Of School Bus Retrofit with Exhaust After Treatment Devices	05/18/01	02/14/02	$49,341	$49,341

CFT: Technology Transfer and Assessments

96058	Moore Consulting	Technical Support, Alternate Fuels and PM Issues, Non-reg. Options	12/11/95	01/31/02	$50,000	$50,000
97061	Rose Communications Inc.	Technical Support, Policy Support & Information, Fuel Cell Task Force Implementation	12/31/96	01/31/02	$50,000	$50,000
97110	Burke, Andrew F.	Review & Assessment of Technical Proposal re: ATTB Ultracapacitor System	06/04/97	08/15/03	$15,000	$15,000
97113	JME Inc.	Review & Assessment of Technical Proposal re: ATTB Ultracapacitor System	05/08/97	08/15/03	$15,000	$15,000
99046	Engelhard Corp.	Field Evaluation of PremAir Ozone Catalyst Technology on AC Units	10/06/98	12/31/10	$0	$0
00045	Arieli, Adi	Technical Assistance in ATTB & Fuel Cell Technology	11/03/99	10/31/02	$30,000	$30,000
00069	Walsh Consultant	Technical Assistance Relating to the use of Alternative Fuels in Mobile Sources	02/17/00	02/28/03	$35,000	$35,000
00078	Breakthrough Technologies Institute	Technical Assistance Related to Development and Commercialization of Zero- & Low-Emission Technologies including fuel cells	01/28/00	01/31/03	$50,000	$50,000
00079	USA Pro & Associates	Technical Assistance Relating to the Development and Commercialization of Natural Gas Engines, Vehicles, and Fueling Facilities	01/08/00	01/07/02	$50,000	$50,000
00098	Katz, Murray	Technical Assistance Pertaining to Fuel Cell Development & Commercialization	02/25/00	02/24/02	$20,000	$20,000
00112	Engine, Fuel & Emissions Engineering, Inc.	Technical Assistance Regarding Alternative Fuel Engines	04/13/00	04/12/03	$35,000	$35,000
00175	Burnett and Burnette	Technical Support for the Evaluation and Implementation of CNG Fueling Facilities	05/31/00	05/31/02	$45,000	$45,000
01026	Beilacqua-Knight, Inc.	Program Support for the California Fuel Cell Partnership	12/18/00	12/31/03	$171,800	$1,755,800
01189	Natural Gas Vehicle Coalition	Cosponsor the 19th National NGV Conference & Exhibition	10/10/01	01/31/02	$5,000	$5,000
01197	Kalhammer, Fritz	Clean Fuels Advisory Group Expenses	10/10/01	02/28/02	$4,000	$4,000
01199	Roan, Vernon	Clean Fuels Advisory Group Expenses	10/10/01	02/28/02	$3,000	$3,000

Contract	Contractor	Project Title	Start Term	End Term	AQMD $	Project Total $

CFT: Technology Transfer and Assessments (cont'd)

01200	Runkel, Brian	Clean Fuels Advisory Group Expenses	10/10/01	02/28/02	$1,000	$1,000
01201	Vanderborgh, Nicholas	Clean Fuels Advisory Group Expenses	05/29/01	02/28/02	$3,000	$3,000
02118	WestStart-CALSTART	Co-Sponsorship the 2nd Annual Clean Heavy Dduty Vehicles for the 21st Century	10/10/01	08/31/02	$5,000	$300,000
02135	SunLine Transit Agency	Cosponsor Educational Outreach Program	11/08/01	03/31/02	$50,000	$548,000
02136	University of California Irvine	Renew Participation for Three Years in National Fuel Cell Research Center at UCI	11/08/01	10/31/04	$90,000	$1,250,000

APPENDIX C

Final Reports for 2001

ALTERNATIVE FUELS - ON -ROAD APPLICATIONS

AQMD Contract # 00091 *October 2001*

Develop and Demonstrate Advanced Natural Gas Engine Electronic Controls

Contractor
Cummins Inc.

Cosponsors
AQMD, SunLine, Cummins

Project Officer
Michael Bogdanoff

Background

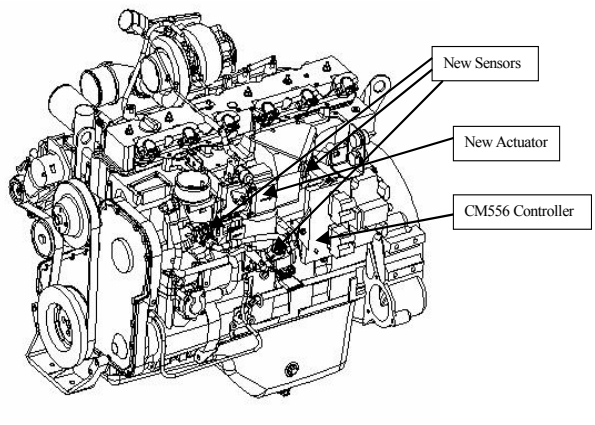
The Air Quality Management Plan adopted by the AQMD Board has targetted the reduction of diesel exhaust emissions in the Basin, from both air quality and toxic consideration. Natural gas heavy-duty engine technology is commercially available for transit applications and in limited options for truck applications. Cummins Inc. has taken the lead in the development of spark-ignited natural gas heavy-duty engines and has certified the C8.3G engine to ARB optional low-NOx standards. Electronic controls are crucial to achieving and maintaining low emissions throughout the driving cycle.

Project Objective

This project was to develop and demonstrate the next-generation electronic controls for Cummins natural gas engines. Specifically, this project was to design, validate and implement improved electronic subsystems that will also help test, diagnose and provide product support for the new C8.3G Plus engine. Following the development of the electronics system in the laboratory, a prototype C8.3G Plus engine was demonstrated at Sunline Transit in Riverside County.

Technology Description

This project was planned to develop and implement into production a modern electronic engine management system that achieved the above objective and specifically develop the electronic service tools needed for these advance technology engines. Also undertaken were the development and launch of the publications required to support problem troubleshooting and diagnosing needs of the field support organization. Below is a model of the engine with the new controller, sensors and actuator.



The project deliverables were divided into four major tasks:

Task 1 - Develop and Design Advanced Electronic Control Module (ECM)

The development of the engine and control system was covered largely by a separate contract with CEC and GTI (California Energy Commission and Gas Technology Institute). The deliverable for this task was to ensure that the needs for the Service Tools portion of development are covered during the engine development process. A summary of the electronic system development was a deliverable for this project. The two major elements of the control system development were: development of the control system and development of the capability to operate with a wide range of gas compositions.

Task 2 - Develop, Design and Demonstrate Advanced Electronic Tools

In this task, the design and development of the Insite electronic service tool was undertaken. The tool is a PC based system that interfaces with the engine electronic controller to help the field

service engineer to troubleshoot fault codes and diagnose problems.

Task 3 - Develop Electronic Service Publications

Publications were developed and released to the field for repair manual, engine and OEM wiring diagrams, service tool profile and fault code & diagnostics.

Task 4 - Demonstrate the C8.3G+ engine at Sunline Transit

One field test engine was placed with Sunline Transit as a bus end user to evaluate the engine technology in this application. Data was collected for the engine during the field test duration. Good performance and reliability were demonstrated.

Status

The development of the electronic engine management system is complete. The engine has been certified to ULEV emissions levels with catalyst with the EPA.

The design of the electronic controller hardware and software has been completed, verified and launched into production. The service tool (Insite) and publications were developed and released to the field organization. The performance and reliability of the control system have been validated through engine dynamometer and field tests. A ten-vehicle field test program included one vehicle at Sunline Transit, which was part of this contract.

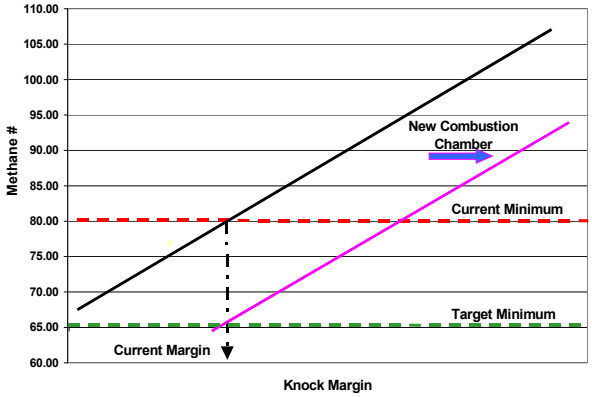
Results

Certification (FTP cycle) test results were:

NOx 1.53 gm/hp.hr and 0.008 PM gm/hp.hr

These levels are significantly better than the target. A family emissions level for NOx was established at 1.8 (gm/hp.hr). For CARB, the engine was certified to a low NOx option of 2.0 (gm/hp.hr). The Supplemental Emissions Test (SET) required for post 10/02 certification was also conducted and the test results showed good compliance to this upcoming standard.

The graph below shows that with the advanced electronic controls and a reduced compression ration (10.5:1 to 10:1) it was possible to reduce the minimum methane number requirement from 80 to 65.



The development program has achieved all planned targets and goals and the C8.3GPlus was production launched in July 2001. A Final Report was prepared in October 2001

Benefits

Three clear benefits resulted from this project:

Lower emissions: A reduction of 30% in the NOx emissions certification levels for the C8.3G.

Advanced electronic tools: Higher reliability and uptime in field.

Wide range fuel capability: The new electronic controls in the C8.3G Plus engine allows utilization of a wider range of natural gas compositions, increasing the market penetration potential of this engine.

Project Costs

The total project cost was $602,550. The cost sharing was: Cummins $325,000, Sunline Transit $12,550 and AQMD $265,000.

Commercialization and Applications

This product has been successfully brought to market and has been in production since July 2001. Acceptance has been excellent, with over 500 engines already ordered for the transit bus market, including 108 engines for Southern California. Interest is also growing in the refuse market where an order of 20 refuse and recycling trucks has been placed on the C8.3G Plus.

AQMD Contract 01031 *May 2001*

Establishment of Design Practices for CNG Trucks and the Use of Methane Detection

Contractor

USA PRO & Associates

Cosponsors

PACCAR, John Deere, Cummins Engine Co., Detroit Diesel, General Motors, Ford Motor Co Mack Trucks, Amerex, SB Dual Spectrum, Freightliner, Natural Gas Vehicle Coalition, Bering Trucks, International Trucks, Gas Research Institute.

Project Officer

Michael Bogdanoff

Background

The AQMD has identified the use of low-emission, light-, medium-, and heavy-duty vehicles as necessary to achieve ambient air quality standards in the South Coast Air Basin. Commercial natural-gas vehicles have demonstrated emissions at least one-half that of conventional diesel vehicles.

A review and analysis of the development of medium- and heavy-duty natural-gas vehicles led to the development of SAE J2343 for LNG Trucks. This safety document was adopted by the California Highway Patrol - Title 13 and the California Pressure Vessel Code - Title 08. These provide clear, concise and comprehensive criteria for the design and integration of LNG fuel systems for trucks. The lack of similar guidelines and regulations for medium and heavy-duty CNG trucks clearly established the need for this work.

Project Objective

The objective of this project is to help ensure that CNG truck on-board natural gas fuel systems will be safe, reliable and cost-effective to install and maintain. The first part of the project will develop a recommended practice document (SAE J2406) for compressed natural gas (CNG) onboard fuel systems for medium and heavy-duty trucks. Furthermore, this project will help to develop recommended practices for natural gas detection related applications for both CNG and LNG automotive applications.

Technology Description

Natural-gas fueling systems consist of fuel storage tanks (either CNG or LNG), associated tank mounting hardware, pressure relief devices, pressure regulators, and associated valves, fuel lines, sensors and wiring. The SAE recommended practices for properly installing this equipment on a truck chassis needs to be developed to ensure safe operation. This includes considerations for refueling, maintenance, manufacturer's recommendations for each type of truck and application. Much of the needed information for such practices exists for automobiles; however, there are no documents that apply to medium and heavy-duty CNG vehicles.

Status

In the past a significant effort has been expended to develop the automobile CNG applications. Numerous documents are available that are specific to the light duty applications for cars and pickup trucks. Reference guides for integration and use of natural gas fueled vehicles, individual CNG equipment supplier data sheets and a significant compilation of industry information and recommendations. However, the information does not generally apply to medium-heavy duty trucks and the OEM members as well as the California Highway Patrol agree that there was a definitive need for a recommended practice for CNG trucks. As a matter of reference, the SAE process for the final document would be followed in order to insure acceptance by each heavy-duty original equipment manufacturer (OEM).

Numerous committee meetings were held at the SCAQMD Diamond Bar, California location to formulate the recommended practice. The

committee voted on the final document through the SAE process and the project was completed prior to the May 2001 due date. The project's final report was due for submittal in May of 2001.

Results

The SAE J2406 recommended practice document is specific to CNG heavy-duty trucks. However, it does summarize the heavy-duty OEM's onboard fuel system recommendations that can be utilized for the design, manufacture, and maintenance of:

- CNG Full-Size Transit Buses
- CNG Medium-Duty and Heavy-Duty Trucks
- CNG School Buses

This SAE recommended practice document is intended to serve as both a user primer, and a tool to help practicing designers, manufacturers, and users of CNG trucks avoid potential problems with CNG fuel systems and to locate appropriate references to learn more about specific topics. The information and data was developed in order to cover a wide spectrum of engineering information that relates to the original equipment and safety considerations for CNG heavy-duty applications.
The efforts supported by the SCAQMD have focused on issues specific to compressed natural gas trucks and other medium and heavy-duty vehicle platforms. The effort has included the following activities:

- Provided a medium heavy-duty working group forum for key engine and chassis organizations
- Determined industry practices and issues regarding truck CNG fuel system integration
- Identified key compliance issues for the truck industries use of CNG onboard fuel systems
- Determined vehicle maintenance practices system integration issues
- Developed a SAE recommended practice pertaining to building and maintenance of compressed natural gas medium and heavy-duty trucks
- Incorporated recommended practices into the reference guide for each truck OEM
- Development of odorant information/review materials and methane detection considerations

Benefits

The results of the program will provide the buying customer as well as component suppliers with a clear recommended practice document for CNG trucks. Furthermore, the document is intended to help designers, manufacturers, and users of CNG avoid potential problems and locate appropriate references to learn more about specific trucks and their individual applications.

The target audiences for this document is wide spread and include: original equipment manufacturer (OEM) medium- and heavy-duty truck builders, OEM transit and school bus builders, suppliers of natural gas fuel system components and subsystems, fleet procurement and management personnel, vehicle end users and maintenance staff, and vehicle conversion/vehicle retrofit companies.

Additional considerations for a broader audience will be incorporated upon completion of: the SAE final approval process, adoption by the California Highway Patrol [Title 13] and adoption by the California Pressure Vessel Code- OSHA [Title 08 regulations for motor vehicles].

Project Costs

CO-SPONSORS	AMOUNT
Gas Technology Institute	$ 30,000
AQMD	$ 63,000
Industry Members	$ 117,250
TOTAL	$ 210,250

Commercialization and Applications

The result of this project was the final development of the SAE J2406 recommended practices document. The document has the approval from all of the industry OEM's and has been submitted for final approval by the SAE Truck and Bus Committee.

Furthermore, upon SAE approval this document will provide industry guidelines for the design, installation, and maintenance of CNG fuel systems on medium- and heavy-duty trucks.

The California Highway Patrol [Title 13] and The California Pressure Vessel Code-OSHA [Title 08] will also introduce the document for adoption as a California regulation upon acceptance by SAE.

AQMD Contract # 99157 **October 2001**

On-Road Development of Enhanced Caterpillar® C-12 Dual-Fuel™ Truck Engine

Contractor
Clean Air Partners, Inc.

Cosponsors
National Renewable Energy Laboratory (NREL), Jack B. Kelley Trucking, Caterpillar Engine Company, Gas Research Institute, Power Systems Associates, Clean Air Partners, AQMD

Project Officer
Michael Bogdanoff

Background

The Dual-Fuel engine (natural gas with diesel pilot injection) provides the low NOx emissions of a spark-ignited, lean-burn natural gas engine, with the high efficiency and power output of a diesel engine. The base Cat® C-12 Dual-Fuel engine is rated 410-hp and 1250 lb-ft of peak torque. It has the highest rating of any natural gas on-highway engine manufactured. However, a study of fleet operators indicates that 425-hp and 1450 ft-lb of torque are the minimum performance preferred by the majority of commercial fleets. Therefore, with a slight increase in horsepower and torque and a potential for reduction in particulate matter emissions, the C-12 Dual-Fuel engine could satisfy fleet users as well as reduce emissions.

Project Objective

The goal of this project was to develop an enhanced version of Caterpillar® C-12 on-highway, heavy-duty, Dual-Fuel truck engine with increased rated power and peak torque and the following specifics:

- 425 hp at 1800 rpm and 1450 lb-ft at 1200 rpm
- California low NOx of ___ g/bhp-hr and LEV emission standards
- Higher natural gas substitution rate
- Fuel economy of the base C-12 Dual-Fuel engine
- Reduced particulate matter emissions compared to the base C-12 Dual-Fuel engine.

A pre-commercial demonstration in the South Coast Air Basin would be conducted with 5 trucks.

Technology Description

Both CNG and LNG are known to be vulnerable to fuel quality deterioration. Measures to increase the engine output usually result in an increased tendency to engine knock. An effective anti-knock control system can protect against this event and provide the opportunity to reduce knock safety margins incorporated in the base C-12 Dual-Fuel engine software.

To achieve the LEV rating without compromising efficiency, performance, or other emissions commonly associated with retarded timing for NOx reduction, an alternative method is required. The effect of air charge temperature (ACT) is well published that lower ACT yields lower NOx emissions. Lower ACT also reduces knock tendency in Dual-Fuel engines. Cooler air intake temperature, therefore, allows the brake mean effective pressure to be increased without the risk of knock.

The following technologies were investigated during this project:

1. Knock detection and control
2. Turbo expansion to lower ACT
3. Air pressure booster in addition to the stock turbocharger

Figure 1 shows the installation of the hydraulic supercharger on the test engine.

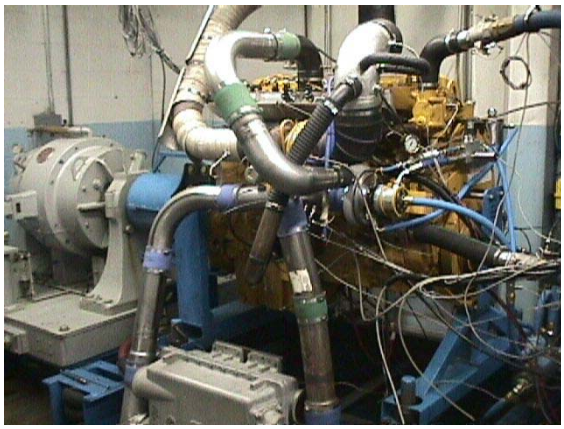


Figure 1

Status

These technologies were investigated during this project. Due to the announcement made by Caterpillar on March 6, 2001, that all Cat® truck engines including C-12 will employ the new engine technology called ACERT™. The MEUI fuel system currently employed on the C-12 engine will be replaced with the next generation HEUI™ fuel system which requires engine design change. The technologies developed during this project becomes inappropriate. It was determined by all parties concerned that this project should be terminated at the end of March 2001.

Results

The hydraulic supercharger (HS) has its merit on boosting air mass flow required by the enhanced C-12 Dual-Fuel engine at engine speeds below 1400 rpm. The HS has also proven to be a suitable and valuable device in identifying the turbocharger performance characteristics required by the enhanced C-12 Dual-Fuel engine. Figure 2 shows the NOx emissions at various hydraulic pressures supplied to the HS turbine. NOx emission decreases as hydraulic turbine pressure increases. This is due to the leaner air and gas

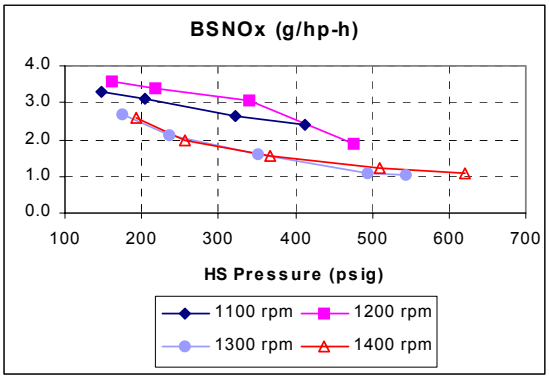


Figure 2

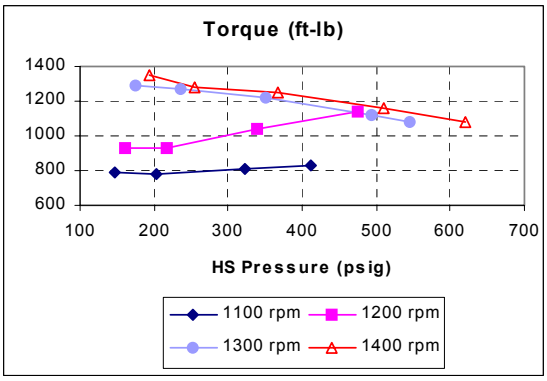


Figure 3

mixture at higher hydraulic turbine pressure. Figure 3 shows maximum torque output at 1100 ~ 1400 rpm while HS hydraulic turbine inlet pressure was modulated between the maximum and minimum pressures by the HS electronic pressure regulator.

Benefits

The base Cat C-12 Dual-Fuel engine has the highest rating of any natural gas on-highway engine manufactured. The technical investigation and development conducted in the project indicates the enhanced version of C-12 Dual-Fuel engine will produce 425 hp and 1450 lb-ft torque, which will satisfy fleet users as well as air quality advocates.

Project Costs

The actual costs and originally allocated costs of the project are tabulated below:

Funder	*Allocated*	*Actual*
Caterpillar	*$274,000*	*$274,000*
Power System Associates	*$ 75,000*	
Gas Research Institute (GRI)	*$163,094*	*$163,094*
Jack B. Kelley	*$625,000*	
NREL	*$617,705*	*$291,000*
AQMD	*$492,453*	

Fundings from Caterpillar and GRI were directed to the completion of laboratory base engine development.

Commercialization and Applications

Due to the unforeseen adaptation of the ACERT™ technology on the C-12 truck engines by Caterpillar, the technologies developed during this project become inappropriate. Commercialization

of these technologies as originally envisioned is, therefore, not possible.

The selected knock sensor will require less effort to integrate the sensor's electronic to the Dual-Fuel truck engine's electronic control module. Knock detection and control strategies were developed in this project, were not thoroughly evaluated and tested, however.

There are concerns on commercial viability of the enhanced C-12 Dual-Fuel engine having the hydraulic supercharging system incorporated. A single variable geometry turbocharger optimized for Dual-Fuel engine will be the best solution.

ALTERNATIVE FUELS - INFRASTRUCTURE

AQMD Contract # 01179 *December 2001*

Clean Fuel Infrastructure & Demographic Optimization Study

Contractor

Arthur D. Little – Acurex Environmental

Cosponsors

AB 2766 Mobile Source Air Pollution Reduction Review Committee

Project Officer

Larry Watkins

Background

The AQMP has identified the use of low-emission alternative-fueled vehicles (AFVs) as a key strategy to achieve emissions reductions in the mobile source sector. It is well known that an essential element of AFV deployment is to develop a sufficiently large and user-friendly network of stations that dispense alternative fuels. To help guide the expenditure of incentive funds by government agencies in the AFV fueling infrastructure, Arthur D. Little is preparing a planning tool that selects the most viable stations and applies "demographic optimization" factors. The tool can be used to determine where new stations are most needed in the South Coast Air Basin, by comparing attributes and locations of existing facilities versus proposed stations. It also can be used to assist potential AFV fleet owners to understand the potential and viability of a prospective new fueling station.

Project Objective

A key project objective is to develop criteria and a methodology for prioritizing AFV infrastructure projects for which government funds are sought. Using the criteria and methodology developed, a second objective is to build an application in Microsoft Excel that allows for data queries of stations and users. The project is being equally cost shared by the AQMD and the MSRC; AQMD funding has been applied to the now-complete first phase. The MSRC cost share is now being used to complete the planning tool, as described below.

Technology Description

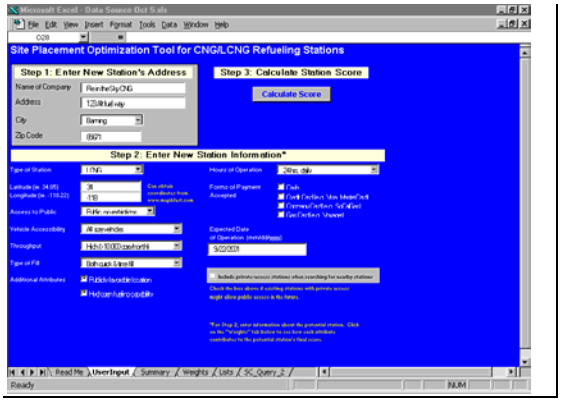
The fueling station optimization tool is designed to enable a user, such as an evaluator of funding proposals under the Carl Moyer or AB 2766 incentive fund programs, to compare proposed stations with existing stations and other potential stations. This novel tool is built in Microsoft Excel. The user enters information about a potential station, including technical and geographic attributes such as location, size, fuel type, fast or slow fill, hydrogen fueling capabilities, and hours of operation. These attributes are then scored and compared with existing stations, using a user-defined scale that can be weighted and modified as needed. The results are provided on an easy-to-read output sheet. The user may also query the database to determine the number of stations with particular attributes and their proximity to the proposed station.

Status

In the first phase of the project that was funded by AQMD, the criteria and methodology for prioritizing fueling projects was completed, and the planning tool was designed. To date, the tool allows the user to enter potential station data using a graphical form, as seen below, and it provides a score for potential stations based on their proximity to existing stations and several attributes. The tool also queries stations within a 1-, 2.5-, and 5-mile radius of a potential station.

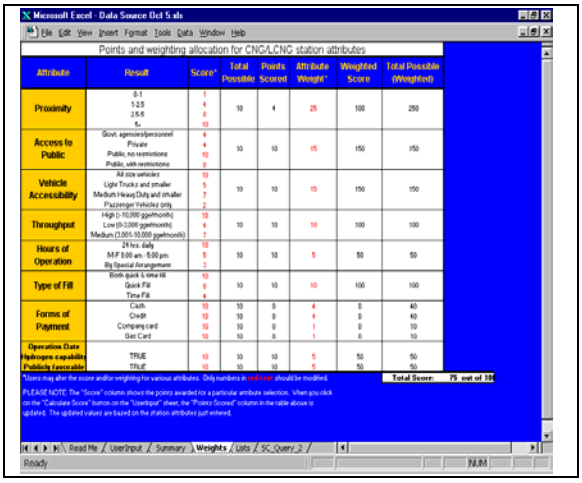
During the project Arthur D. Little met with AQMD to review databases of stations and fleets that might be helpful in developing the optimization tool. Although the stations were a good starting point for the tool's base case data, fleet information that specifies fuel type was not sufficient to populate the model. As a result, in the first phase, the model did not include location of fleets as an attribute to contribute to a station's score. The phase 2 follow-on work under the

MSRC contract will increase functionality with the addition of fleet data attributes and comparisons of potential stations against each other.



Results

The optimization tool currently searches a database of 92 stations in 52 cities in the South Coast Air District. It tests and scores ten attributes, to which the user may assign importance, as seen in the table of weighting values below. Tests of the model have produced accurate scores for hypothetical stations throughout the District.



Although the AQMD-funded portion of the project has ended, the model is undergoing further development and refinement in order to meet all of the objectives, and when complete it will be provided to both the AQMD and MSRC.

Benefits

A major benefit of this planning and optimization tool is that government funds can be better appropriated to maximize the use of AFVs and fueling stations in the South Coast Air Basin. Once fully developed and deployed, the tool's users can determine which of several potential fueling stations are in the best locations and have the best attributes in relation to existing stations, fleets, and potential fleets. The impact of such a tool can be very significant, especially because the tool can continue to be updated by the user as more fleets are established and as potential stations are built and put into operation.

The actual benefit of the tool will depend on how much data is available to the user. For example, fleet data was not readily available and consistent when building the tool. As this data improves and is better documented, the tool's potential will also increase.

Project Costs

The actual cost of the project to date has been the $25,000 contributed by AQMD. Entering the second phase, another $25,000 from the MSRC will be used to complete the project. These costs are the same as identified in the AQMD Board Letter.

Applications

The deliverable for the project is the AFV fueling station planning tool, which can be used as a stand-alone model or as an input to a GIS (Geographic Information System) application. SCAQMD and MSRC staff will use the tool to assess and evaluate proposed AFV fueling stations and select the "optimal" stations in various areas of the South Coast Air Basin. A potential follow-on application of the tool is to make it a web-based program that enables any on-line user to rate the value of installing a fueling station in any given area. Even if not web-based, the program could be provided to potential clean fuel fleet managers to help them plan stations based on the location, routes, and fueling requirements of their AFVs.

Follow-On Work

As noted above, the planning tool for AFV stations continues to be developed through follow-on work with the MSRC. This ongoing work involves improvement of data manipulation, file management, ease of use, and addition of fleet attributes. Also, fields are being added for new parameters and attributes, such as county designation and indication of environmental justice areas. Completion is expected in Q1 2002.

FUEL CELL AND HYDROGEN TECHNOLOGIES

AQMD Contract # 96116 **November 15, 2001**

Commercialization of Small Scale Fuel Cells

Contractor

Small Scale Fuel Cell Commercialization Group**, (Polydyne Inc.)**

Cosponsors

Twelve electric and gas utilities, $10,000 each

Project Officer

Ranji S. George

Background

Fuel cells are among the cleanest alternatives available to generate electricity and heat. Its emissions are near zero, with the potential of high energy efficiency. Sizes of fuel cells could range from small scale to megawatt scale.

Project Objective

To assist the wide scale market entry of residential fuel cells to provide clean electricity and heat to the household. A coalition of gas and electric utilities from across the nation was formed to target this market penetration.

Technology Description

Among the competing fuel cell technologies, PEM fuel cell was the most advanced for residential fuel cell applications. A residential fuel cell, sized between 5 kW to 10 kW, was expected to reform natural gas, generate pure hydrogen to be used in a PEM fuel cell stack, to supply clean power and heat to the house. Batteries would supply supplement power.

Status

AQMD supported a coalition of utilities organized by Polydyne Inc. to accelerate the entry of residential fuel cells. This project had two phases. Phase I involved a demonstration stage, in which a RFP would be issued and demonstration units were to be supplied by vendors selected competitively. Following installation, these demonstration units were to be tested and analyzed. In a subsequent phase, if these initial units proved successful, mass orders for commercial units were to be placed.

The project could not be completed because the technology for the residential fuel cell had not progressed adequately. During the project, it was noted that several manufacturers had made considerable strides in developing PEM fuel cell stacks. However, progress in developing small scale fuel cell reformers lagged behind those of the stacks. The project had to be terminated.

A key participant in the original group of utilities, Detroit Edison, spun off with its own small scale fuel cell program and helped form Plug Power, which has emerged as an important vendor in this field.

The project main success was to raise the awareness of the potential for small scale fuel cells. Today, after initial skepticism, several vendors are positioning themselves in this market.

Develop an Improved Electrode for Direct Methanol Fuel Cell Using Magnetron Sputtering

Contractor
Cal Poly Pomona Foundation Inc

Cosponsors
N/A

Project Officer
Howard Lange

Background

A conventional fuel cell uses hydrogen and oxygen to make electricity directly with water as a by-product. A more practical version for vehicular and distributed generation applications uses methanol and air as a source of hydrogen and oxygen. The Direct Methanol Fuel Cell (DMFC) approach transforms a methanol-water mixture into hydrogen directly at the anode catalyst The hydrogen is transported through a Proton Exchange Membrane (PEM) to the cathode side where it combines with the oxygen from the air to form water**.** DMFC technology made significant advances in performance over the past several years. However, current construction techniques are labor intensive and are believed to use an excessive amount of catalyst materials.

Project Objective

The objectives of this research were: (1) to determine the feasibility of using magnetron sputtering techniques to deposit catalyst on both sides of a PEM for the fabrication of a DMFC, (2) to evaluate the use of ion-beam etching of the PEM, and (3) to investigate less expensive alternative materials as a supplement or replacement for the expensive catalyst materials currently used. The goal was to reduce the costs associated with DMFC manufacturing by developing techniques more amenable to automation and material optimization.

Figure 1. Magnetron Sputtering and Ion Beam Etching Laboratory Apparatus

Technology Description

The conventional DMFC construction involves a series of steps to apply the catalyst material to the PEM. The PEM is prepared by roughening the surface with sandpaper, etc., to improve the catalyst bond and electrical contact with the membrane. A suspension containing catalyst powder, Nafion^{TM} powder, and alcohol, is applied by brush, roller, etc., followed by drying step, e.g., an air blower. The process may be repeated several times to achieve the desired thickness. The membrane, with catalysts bonded on both sides, is hot-pressed to carbon fiber papers to form the complete Membrane Electrode Assembly (MEA).

The construction techniques described above are difficult to implement as an automated

manufacturing process due to the problems associated with thickness and uniformity control. In addition, the MEA produced with these methods are believed to be using an excessive amount of expensive catalyst material, e.g., platinum and ruthenium. This concern has led to recent work to evaluate the use of ion-beam etching to roughen the surface and magnetron sputter deposition techniques to apply the catalyst materials on the PEM substrate. These technologies are currently used in other high volume manufacturing settings where reliability and quality control are paramount.

Status

This project was completed in September 2001and the draft final report, with complete technical details, is being reviewed by AQMD.

Results

The project demonstrated, to our knowledge, the first successful sputtered cathode catalyst, and the first DMFC with sputtered catalyst electrodes on both sides. It was demonstrated that magnetron sputtering permits the deposition of amorphous homogeneous films, allowing better control of product quality and better utilization of catalytic materials than is possible with standard metallurgical methods. The amount of catalyst used in this study was roughly an order of magnitude less than that used in the best conventionally made MEA for a DMFC fuel cell. The catalyst utilization (watts/gram) for the sputtered films was about three times greater than the conventionally made MEA. However, the peak power density (watts/cm^2) was about one fifth of the later. These data show that the fuel cell performance increases with the amount of catalyst, but each additional increment has diminishing returns of power density. It is evident that further improvements in the catalyst structure may be required to bridge the gap between catalyst utilization and power density.

It was also determined that ion-beam etching is a viable substitute for the conventional abrasive techniques for preparing the PEM for the catalyst. The ion-etch can be precisely controlled, and does not leave any abrasive residue. In addition, it was found that the cathode would not perform without the etch, i.e., the sputtered platinum coating on a smooth PEM substrate literally sealed the surface - preventing the transport of gases and liquid. The etched surface was sufficiently porous to permit the necessary transport processes to take place.

The best known catalyst materials for DMFC were used in this effort as a baseline performance reference for testing alternative catalyst materials. However, most of the time was used to understand the baseline itself.

Benefits

Subject to further refinement of these techniques, ion etching and magnetron sputtered deposition of catalyst on the PEM material provides a potential method for high-volume, lower-cost manufacture of DMFC with a commercially acceptable level of quality control. This manufacturing method, when fully developed, can potentially remove a significant barrier to commercialization of DMFC technologies.

Project Costs

The project costs should be several thousand dollars under the original budget of $183,800. The final details are not available at this time.

Commercialization and Applications

The commercial application of magnetron sputtering techniques to DMFC production could have a near-term impact on manufacture of DMFC units for use in distributed generation applications, where size and weight are less critical. However, improvements in the power density, as described above, will probably be required to make this manufacturing method useful for most vehicular applications.

AQMD Contract #00029 *November 2001*

Proton Exchange Membrane Fuel Cell Grade Methanol Fuel Quality Study

Contractor

Dbb Fuel Cell Engine Corp
(Xcellsis Corp)

Cosponsors

Methanol Foundation, Methanex Corp., Daimler Chrysler, Ford & AQMD

Project Officer

Paul Wuebben

Background

The AQMP identifies the use of alternative clean fuels, including fuel cell vehicles, as a key attainment strategy. Major auto manufacturers are developing proton exchange membrane fuel cell (PEM-FC) vehicles as an important means of enhancing their technological options to comply with the ARB's ZEV standards. The ARB has adopted an emission credit protocol which will allow manufacturers the option of obtaining partial ZEV credits for fuel cell vehicles, including those which utilize methanol reforming.

Project Objective

One of the FC technologies under development by DaimlerChrysler and dbb FCEC is based on the reforming of methanol to supply hydrogen to the fuel cell stack. Primary challenges in expediting the technology are to provide fuel which has the proper specifications for reformers, and to utilize reformer catalysts which are most suitable for the fuel quality expected and desired at retail refueling stations. The development of such a specification requires a balancing of the needs of the vehicle and the logistical and quality control realities of retail fuel distribution.

The objectives of the proposed project are to (1) identify the range of fuel quality additives and materials which may be present in the current methanol fuel distribution infrastructure; (2) assess the possible detrimental effects such fuel constituents may have on fuel cell operation and

catalyst efficiency and durability; and (3) to formulate alternative approaches to mitigate these undesirable effects. This evaluation is expected to contribute significantly to the understanding of the key fuel quality parameters and the sensitivity of specific catalyst formulations to existing and potential fuel specifications.

Technology Description

The following assessments were completed:

- A review to identify the compounds which can impede methanol conversion over copper zinc oxide catalysts, with a summary of the properties of these compounds and their probable impact when introduced in the reformer.
- A detailed chemical analysis of available methanol samples from selected sites, spanning all commercial grades currently offered within the state. This information helps define the boundary conditions for the concentrations of various compounds which exist in retail grade fuel supplies.
- A chemical analysis of the fuel infrastructure distribution chain to determine if contaminants are avoidable through stricter quality control practices within the distribution system, or if their presence is indicative of a more pervasive and systemic problem.
- An analysis of the additives currently used in commercial grade to determine which additives are appropriate for application to PEM-FC vehicles. A variety of optional additive compounds or families of compounds were identified to address possible concerns about flame luminosity,

taste, fuel color, etc. A full chemical analysis was conducted on each of the candidate additives.

- A reformer degradation analysis was conducted based on the full array of fuels, additives and potential contaminants. This testing utilized proprietary reformer evaluation hardware which allowed for long term automated testing of small quantities of reformer catalyst. The results of this testing were benchmarked and compared to pure reagent-grade methanol. An initial screening was conducted to determine the optimal combination of fuel properties, additive packages and distribution procedures.

Status

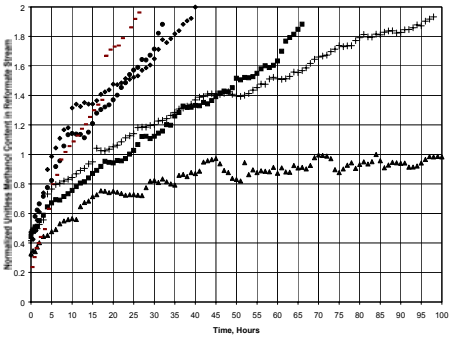
This study obtained key information which can be used as a benchmark for future studies of reformer sensitivity to various grades of methanol. The continuation of the work initiated in this study is now based in Neburn, Germany.

Results

Dedicated or appropriately cleaned methanol systems are essential to ensure that methanol's high purity is maintained throughout the methanol distribution infrastructure. Production-side contaminants can include acetic acid, acetone, and 2-butanone. Petrochemical cross contaminant residues include various hydrocarbons. Leaks in water vessels can introduce water and chloride. Heavy metals are possible from downstream plumbing systems if incompatible materials are used.

For example, galvanized plumbing can be a source of nickel and zinc. There is some concern about the effect of fuel bitterant and odorant additives could have on the methanol reformer's copper zinc oxide catalyst. In general, preliminary results indicate that specific contaminants have a greater effect on reformer catalyst degradation than others do; the absolute level of contamination is not the most important variable. Compared to the manufacturing facility background methanol sample, the other catalyst degradation tests using five other methanol samples showed significant increased levels of degradation, with a general relationship to the level of contamination present in the sample.

The methanol samples were evaluated with a small scale reformer using an accelerated lifetime test protocol. This protocol did not allow for an assessment of the dynamic load, but rather was a means of quickly determining catalyst response. Future study on this issue should assess varying fuel grades over an array of fuel flow rates. This would allow calibration of the accelerated test data to enable predictive capability without requiring extended test periods. The table below provides the degradation results for the hydrogen reformate stream as a function of time for six different methanol samples, normalized to the base methanol sample from a stainless steel drum at Xcellsis's facility.



Benefits

A Joint Study on methanol fuel cell vehicles by DC, BP-Amoco, BASF, Statoil, and Methanex was announced on September 13, 2000. The methanol specification data developed as part of the AQMD-supported study is being assessed as part of this new Joint Study.

Project Costs

The total cost of this project was $479,000. The AQMD provided $205,000, along with $245,000 from Xcellsis, $10,000 from the Methanol Foundation, $ 7,000 each from Ford and DC, and $5,000 from Methanex for the remaining costs..

Commercialization and Applications

The development of a methanol fuel quality specification is of prime importance in the evolution of a commercially viable methanol-based fuel cell vehicle. The highly proprietary nature of this research makes it hard to compare the data from this study with data from other fuel cell and auto manufacturers, oil companies, etc.

Recently, DaimlerChrysler (DC) and Ford sold its interest in Xcellsis back to Ballard.

AQMD Contract # 01047 **November 2001**

Complete Development of Direct Methanol Fuel Cell

Contractor

California Institute of Technology/ Jet propulsion Laboratory

Cosponsors

California Air Resources Board

Project Officer

Howard Lange

Background

JPL is the inventor of the direct methanol fuel cell (DMFC) technology and is developing this technology for application as a vehicle drive or stationary power supply. This technology has the potential to become a liquid-fueled power source for vehicles and/or other applications while having zero emissions of criteria pollutants. The DMFC technology possesses significant advantages in terms of simplicity and compatibility with existing vehicle fueling infrastructure over PEM type fuel cells using hydrogen fuel or those using reformed methanol.

Project Objective

The objective of this project was to design a self sustaining DMFC system capable of delivering 1kW net power over a temperature range of 25^0C to 40^0C. Although this size system is too small to power an automobile, it is large enough to address scaleup issues that are related to large systems.

Technology Description

The DMFC system is inherently clean. It produces electricity by the complete electrochemical oxidation of methanol by the oxygen in air. No emissions have been detected from the exhaust. CO_2 is generated, of course, as it is with any hydrocarbon no matter how efficiently oxidized. Nevertheless, the potential for reduction of this greenhouse gas exists because Carnot cycle (thermodynamic) limitations do not apply to fuel cells. In principle, this can result in higher fuel efficiencies than an internal combustion engine, with consequent reduction in greenhouse gas emission.

With PEM fuel cells, the storage of hydrogen on board a vehicle as well as the lack of an adequate hydrogen fuel distribution infrastructure have been among the obstacles preventing application to automobiles. To overcome this shortcoming reformers are being designed to produce hydrogen from methanol. Reformers do produce emissions as well as greenhouse gases, and respond sluggishly to rapidly varying demands by the fuel cell for hydrogen. They also add weight and volume.

By contrast, the newer DMFC technology utilizes methanol fuel directly without requiring a reformer as a fuel processor. The resulting hardware simplification and performance improvement with respect to varying loads make this a serious competitor to conventional PEM technology for automotive applications.

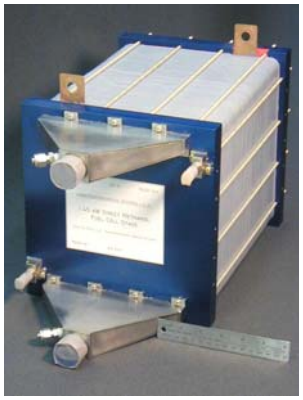


Figure 1. 68-Cell DMFC Stack

Status

The project is virtually complete. The fuel cell stack (Figure 1), which was fabricated by Giner, Inc., has been completed and tested. It has been determined to operate as expected.

The system that is required to support stack operation has also been completed, and the stack has been incorporated into it. A modest amount of wiring is all that remains to be completed before the system is tested. This will be the final phase of this project and will be completed very soon.

Results

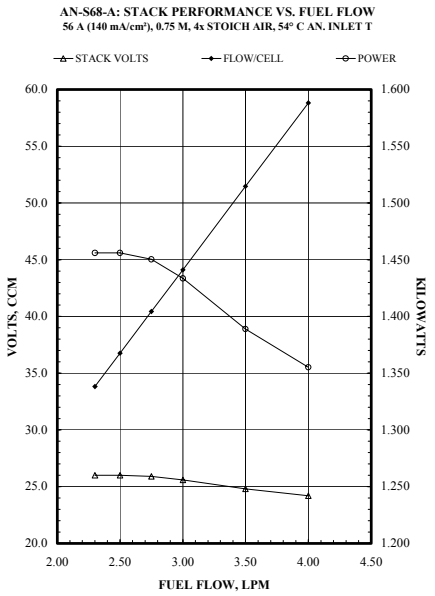
The full size stack, containihg 68 cells, has been demonstrated. It is capable of delivering up to 1.45 kW at 140 ma/cm^2 and an average of 0.384 volt per cell. Figure 2 shows stack output in kilowatts as a function of flow. Because the support system is responsible for parasitic losses of ~300 watts related to the use of pumps, fans etc., the net output can be no greater than 1.15 kw.

It is evident that stack performance actually increases as the fuel flow rate decreases. This behavior is contrary to all data collected to date on small direct methanol fuel cells either configured as stacks or as single cells. The reason for this atypical behavior is not clear, but is suspected to be related to changing fluid dynamics that occur in the biplate or manifold as a function of flow rate. This phenomenon is probably related to the size of the stack and its study will be useful in understanding the behavior of large systems needed for automotive applications.

Benefits

The current performance of the DMFC does not represent its true potential because the technology is still in a relatively early stage. Nevertheless, it is already clear that it is a zero-criteria pollutant emissions technology. The benefits in this respect are self-evident. With regard to greenhouse gas, CO_2 is unavoidably released as with the oxidation of any hydrocarbon. However, the release is in proportion to the efficiency of fuel utilization. The demonstration unit will have an estimated overall efficiency of 20%. Because this efficiency is similar to that of an internal combustion engine, this experimental unit will not reduce greenhouse gas relative to that technology. However, because fuel cell efficiency is not limited by Carnot cycle (thermodynamic) limitations, future improvements in efficiency can be expected with a consequent reduction in CO_2 release.

Figure 2. Performance of 68-Cell Stack



Project Costs

This project, including its predecessor project (SCAQMD Contract No. 98139), will cost $638,500 as originally projected in the research proposal. Of this, $338,500 is contributed by the SCAQMD and $300,000 by the California Air Resources Board.

Commercialization and Applications

Automotive applications are still some years away. The chief barrier to commercialization for such applications is cost. It is estimated that power must cost no more $50/kW while the current technology is roughly estimated to cost nearly $3,000 per kilowatt at modest production levels. While some of the present cost can be attributed to one-at-a-time laboratory oriented production methods, a significant investment in R & D will still be required.

ELECTRIC AND HYBRID ELECTRIC TECHNOLOGIES

AQMD Contract # 01023 *October 2001*

Hotel Shuttle Consolidation Feasibility Study

Contractor
Westart-Calstart

Cosponsors
Los Angeles Convention and Visitors Bureau LACVB), Los Angeles Department of Water and Power, California Energy Foundation, Los Angeles World Airports

Project Officer
Connie Day

Background
Strong growth in passenger traffic at LAX International Airport has driven up demand for hotel courtesy vehicles. The only way the airport can continue to accommodate these vehicles is to work with the hotels on a consolidation program that lowers costs, reduces congestion and emissions while improving the level of customer service and satisfaction.

Project Objective
The project objectives were:

1. To seek a diversified balance of various elements of a comprehensive alternative fuel program for hotel shuttle service at LAX.
2. To deploy clean fuel vehicles at LAX in order to reduce emissions of criteria pollutants in the LAX region.
3. To set a stage for implementation of clean fuel vehicles to comply with the current state and local emission reduction policies such as the AQMD Rule 1194 and the LAX Master Plan Air Quality Mitigation Strategies.
4. To expand this program to other hotels and rental car operations in the vicinity of LAX.
5. To the extent possible, to transfer this concept to other airports in the Southern California region and eventually to other parts of the country.
6. To improve the level of service, increase ridership, reduce cost of operation and meet future service demands between the CTA and the hotels in the LAX area.
7. To benefit from the emission reductions by trading emissions.

Technology Description
The primary strategy for reducing emissions will be to augment the primarily diesel and gasoline shuttle bus fleet with clean fuel buses. Clean fuel buses include electric, hybrid and natural gas. As part of the consolidated shuttle service an advanced traveler information system is proposed. This would consist of a web-site, new signage and automated information at each terminal and shuttle stop and improved information at each participating hotel. The automated vehicle identification system at LAX would provide real time pickup information that would be made available to travelers by a 3rd party provider of real time passenger information systems.

Status
With the Feasibility Study now completed, The Los Angeles Convention and Visitor's Bureau (LACVB) has launched Phase 2 of this project. The goal of Phase 2 is to develop a business plan for implementing the consolidation along with a more detailed assessment of the costs and operational economics for participating hotels. Following the completion of Phase 2, and assuming the results are favorable, LACVB will create an operational entity that will begin the selection and procurement process for new shuttle buses.

Results
The focus of the report was on hotels in close proximity to LAX which currently provide a courtesy vehicle service. The report identifies 22 hotels representing a vehicle fleet of 79 gasoline, 29 diesel and 5 alternative fuel shuttles. Hotel shuttle vehicles account for 15% of all commercial passenger trips into LAX. Each year these shuttles emit 10 tons of Nox, 2.9 tons of

hydrocarbons, 36 tons of CO and 1.8 tons of total particulate matter. Not only do these emissions contribute to regional smog levels, but they also represent a potential health hazard to airport employees working at passenger pickup and drop-off locations.

A comprehensive survey was prepared in order to evaluate the existing operations and services of these hotels. This survey provided information such as the type of service offered, hours of operation, type and number of vehicles operated, passenger volumes, number of rooms and other available shuttle services offered.
The recommended approach to consolidation was to separate the hotels into three groups based on location. Services serving 3 hotels located in the Fox Hills area formed one group. Likewise, the 6 hotels to the south of LAX in El Segundo formed another group. The third group consisted of 13 hotels located along Century Boulevard.
CALSTART identified all commercially available battery electric, hybrid electric, CNG and LNG transit and shuttle buses. The procurement process, training, safety, infrastructure needs and level of manufacturer support was also researched to better understand the requirements for operational support.

A baseline cost analysis was conducted to determine the costs to hotels per room and per passenger for their respective shuttle services. Of the 17 hotels that responded, the average cost per room was $816 and the average cost per passenger was $3.48 annually. The cost per room ranged from $414 to $1190 and cost per passenger ranged from $0.35 to $10.47.

A preliminary system operational plan was developed which included scheduling and route assignment, traveler information needs and a maintenance program. An advanced traveler information system was proposed consisting of a consolidated web-site, new signage and automated information at each stop and improved information at each participating hotel.

Benefits

Emission reduction scenarios for the shuttle consolidation were calculated for a number of scenarios. The recommended approach of using a mixture of electric and LNG/CNG buses yielded the following emissions reductions as compared with current operations:

NOx – Reduced by 60%
ROG/NMHC – Reduced by 42%
CO – Reduced by 25%
PM – Reduced by 26%
Non Exhaust PM – Reduced by 83%
These emissions reductions are based on a shuttle service which services three different groups of hotels. The number of trips is based on passenger demand and the time of day. Headways varied from 5 minutes to 30 minutes based on an assessment of scheduling and route assignments.

Project Costs

The total cost of this project was $175,000 with costs shared across four entities as follows:

SCAQMD - $50,000
LAWA - $$60,000
LACVB - $35,000
CEF - $30,000

Project costs match original projections

Commercialization and Applications

Based on the findings of this report the Los Angeles Convention and Visitor's Bureau is recommending that a clean fuel consolidation service be seriously considered for implementation by LAX hotels. On completion of Phase 2 (Cost Assessment) the Bureau will begin working with the hotels to select shuttle buses which meet the operational and economic needs of the hotels while maximizing emissions reductions. This will require careful selection of shuttle bus technologies and infrastructure.

ALTERNATIVE FUELS - OFF -ROAD APPLICATIONS

AQMD Contract #99067 *June 2001*

Develop & Demonstrate Zero-Emission Technologies for Lawn & Garden Equipment (Zinc/Air Fuel Cells)

Contractor:
Metallic Power

Cosponsors:
Metallic Power, The Toro Company, AQMD

Project Officer:
Mike Bogdanoff

Background
Zinc/Air fuel cell technology developed by Metallic Power could provide an alternative to lead-acid batteries currently used as primary power sources for commercial electric greens mowers, and could also provide power for portable electric gardening equipment. Like internal combustion engines, and unlike batteries, zinc fuel cells are rapidly refuelable; hence they address a primary barrier to widespread adoption of zero emission commercial lawn & garden equipment.

Technology / Clean Fuel Description
All currently available solutions for the mowing of golf course greens have drawbacks. Internal combustion engines emit pollution, are susceptible to leaks of hydraulic fluid into the soil, and produce noise, making them unwelcome to use during the early morning hours on golf courses near homes. This requires golf course superintendents to operate the mowers during the day, reducing the time available for revenue play.

Zero emission alternatives to gasoline internal combustion engine power sources are currently limited to lead acid batteries. Lead acid batteries have a very low specific energy of about 20-40 Wh/kg, so it is difficult to carry enough energy on board the vehicle to complete mowing of 9 greens. Additionally, lead acid batteries must be replaced frequently, making them a high maintenance item, and they present a hazardous disposal issue at the end of their life.

Metallic Power zinc/air fuel cells combine the quiet and zero emission benefits of lead acid batteries with the quick-refuel and energy scalability of internal combustion engines. Zinc/air fuel cells can be sized to meet both the power and the energy requirements of the application, allowing the operator to run the greens mower for as long as desired. Zinc/air technology used in portable power applications allows the user to easily carry just the amount of fuel that is needed.

Metallic Power's zinc/air fuel cell is recharged electrically, but this recharging unit can be packaged wherever it makes the most sense for the application – in a separate recycling unit, as is proposed for the greensmower, or on-board the power source, as could be produced with a backup power source for computers. Quick-change cartridges can make the regeneration for the portable power source as easy as a quick swap of fuel cartridges.

Project Objective
The objective of this project was twofold: Convert a commercial electric greens mower provided by The Toro Company to zinc/air fuel cell power, and produce a prototype portable power source powered by a zinc/air fuel cell, for powering an electric leaf blower and other electric lawn care equipment.

Status
This project has been completed as of June 27, 2001. The final report is on file with the complete technical details of the project.

Results
Performance: The greens mower was converted to zinc/air fuel cell power, in conjunction with lead acid batteries to provide the peak power used when using cutting blades or climbing steep hills, etc. The fuel cell powered mower demonstrated a total of 5.7 kWh of energy capacity available. At an average of 1800 W consumption (an average consumption rate from test data), this would give 3.2 hours of power delivery between refueling.

The Toro greensmower was repeatedly and easily refilled with a full load of new electrolyte and zinc in about 15 minutes per refuel session for the two-cell stack system. However, the fuel cell power source is still heavier than would be optimal for a greens mower. This weight could be reduced significantly through improved design and better management of parasitic loads such as pumps and blowers.

The portable power source was demonstrated powering both a Toro leaf blower and a Black & Decker hedge trimmer. The fuel cell stack itself delivered over 1.7 kW DC of power, with the power source delivering approximately 1.3 kW of AC power.

Benefits: Turf maintenance equipment represents a significant opportunity for emissions reduction.

California alone contains over 1000 golf courses, according to the National Golf Foundation. Total golf courses in the U.S. number over 17,000. Each 18-hole course contain six to eight pieces of large equipment that would be candidates for zero-emission technology, including greens mowers, freeway mowers, rakes, and utility trucks.

Costs: Total expected cost for the program, was $924,000, of which the AQMD's portion was $350,000, and Toro's portion was $64,000. Actual project spending was $1,019,099, with Metallic Power incurring the additional $95,099.

Commercialization Issues and Applications
Golf courses and the communities that surround them appreciate quiet power sources that can be operated for long periods before refueling. Zinc/air fuel cells solve these needs, allowing for early morning mowing, thus enabling the golf course to increase revenue.

In addition, zinc/air fuel cells produce no pollution and are not susceptible to hydraulic leaks into the soil, improving the air quality when compared to internal combustion engines. The fact that zinc/air fuel cells help ensure cleaner air while providing other user benefits reduces the commercialization hurdles.

This project successfully demonstrated the world's first prototype zinc fuel cell-powered lawnmower and portable power source. The two issues that need to be resolved to permit adoption of zinc/air fuel cells as power sources are performance, in terms of specific energy (energy per weight), and cost. Metallic Power is continuing to work on optimizing these two items, to make commercialization a viable possibility.

EMISSIONS ANALYSIS AND HEALTH EFFECTS

AQMD Contract #97122 **November 2001**

Heavy-Duty Vehicle Fleet Characterization for Reduction of NOx and PM Emissions

Contractor

Air Resources Board; Jack Faucett Associates (JFA), subcontractor

Cosponsors

Air Resources Board; AQMD

Project Officer

Mike Bogdanoff

Background

Heavy-duty vehicles (HDVs) contribute significantly to the South Coast Air Basin's mobile source emission inventories for NOx and PM. Seventy percent of the air toxic risk in the South Coast Air Basin is attributed to diesel emissions from HDVs. Emission reduction measures for NOx, VOC and PM from HDVs have been specified in the State Implementation Plan. Knowledge of the specific makeup of the South Coast Air Basin's (SoCAB) HDV fleet will assist the regulatory agencies in designing appropriate implementation programs for these control measures.

Project Objective

The objective was to jointly fund a project with CARB to obtain detailed activity and usage data for HDV operations in the South Coast Air Basin.

Work Description

The scope of work for this project was comprised of three main parts. The first part was a detailed characterization of the HDV in the South Coast Air Basin, including vehicle population, usage patterns, maintenance practices and engine retrofit or repower options. The second part was to develop an emissions estimate in the South Coast Air Basin for each of the years 1997 through 2010 and the year 2020. The third part was development of incentive/implementation strategies to accelerate the introduction of low-emitting heavy-duty engines, and an estimation of emission benefits derived from each specified alternative.

Data on HD fleets was collected primarily through telephone surveys. This data was augmented with data from the CARB and DMV and data generated by global positioning system (GPS) equipment during this project.

Status

JFA and its subcontractor collected data pertaining to detailed HDT activities and patterns in the SoCAB. Data collection involving GPS equipment could be broken down into four steps: Recruiting, Scheduling, Instrumentation, and Data Processing/Analysis. The JFA team conducted the first three parts. The ARB handled the entire Data Processing/Analysis portion.

Logistical constraints and other factors dictated that the truck population targeted for the survey efforts be stratified into three manageable groups. All truck fleets were classified as Small (1-3 trucks), Medium (4-100 trucks) or Large (over 100 trucks). Collecting information from each group required different approaches, and surveys were conducted in different stages. A description of the sampled fleets and trucks represented in the telephone survey are found in the final report.

The application of GPS technology to collect truck data was challenging. A data set from a limited sample of HDTs was developed for this study. The ARB has been processing and analyzing the data collected and has provided the JFA team a brief summary of HDT activity information collected. The GPS information made available by the ARB staff is partly summarized in Table 1 below.

The sample data were combined with other data from the ARB, the California DMV, the US Bureau of the Census, and the US Department of Transportation to develop a profile of trucks operating in the SoCAB.

Results

It was estimated that the number of HDTs registered in the SoCAB in 1998 were about 302,000 out of a statewide total of about 780,000. The distribution of trucks by fuel type and fleet size was similar throughout the state. The likelihood that a truck registered anywhere in the state would operate in the SoCAB increases with the vehicle's Gross Vehicle Weight (GVW). For trucks registered outside the SoCAB, it is estimated that about 15 percent of the light-heavy trucks and 45 percent of the super-heavy trucks will operate in the SoCAB some time over the year. It is estimated that about 185,000 gasoline- and about 180,000 diesel-HDVs operate in the SoCAB.

The survey sought to gather information on the characteristics of trucks operating in the SoCAB. For example, the survey indicated that about 4.4 percent of HDVs owned by fleets had engines that were newer than the age of the truck. About 30 percent of the HDVs were vintage year 1987 and older, and about 35 percent were 1994-98 vintage. The survey also indicated that trucks used in daily rental were much newer on average, while construction, service/utility and waste-hauling vehicles are considerably older than the average. The average mileage of older trucks is less than that of newer trucks.

Small fleets (1-3 trucks) are more likely to operate locally (less than 50-mile range) while about 40 percent of the large fleets (>100 trucks) and 54 percent of their vehicles operate in long-haul service. Truck range was also a function of the type of service provided. The likelihood that a truck was centrally fueled rose from only 20 percent in small fleets to over 70 percent in large fleets. It is estimated that there are about 106,000 HDVs in the SoCAB that are centrally fueled. Twenty percent of the fleets operated their vehicles six days per week, and 20 percent operated their vehicles seven days per week.

Benefits

This study evaluated a number of incentive options that would encourage trucking and transportation industries to adopt measures and technologies that could reduce emissions. JFA considered four major pollutants when calculating emissions (NOx, PM, HC and CO). JFA also considered three different levels of hypothetical penetration percentages (1%, 5% and 20%) to examine varying degrees of effectiveness of the incentive options. The penetration levels can be interpreted to mean the either a set percentage of the targeted population will change their behavior (e.g. convert their vehicle to an alternative fuel), or the target population will change their behavior by a set percentage (e.g. reduce their idling time).

A summary of the major finds with respect to emission reduction incentives is:

1. For reducing NOx emissions, reducing idling time appears to be the most promising.

2. For reducing PM emissions, new alternative fuel vehicles (AFVs) or converting conventional HDVs to AFVs appears to have the greatest PM reduction.

3. For reducing HC and CO emissions, an incentive strategy that shifts the operating hours of HDVs would be most promising.

Project Costs

The total cost of this project was $200,000. The ARB and AQMD contributed $100,000 each for this study.

Commercialization and Applications

This project did not develop any technology that could be commercialized. However, the incentives analysis indicated that existing commercial technology for limiting HDV idling would be beneficial for NOx emission (and reducing fuel consumption) and that commercial alternative fuel engines and vehicles will provide PM benefits for the SoCAB (reference AQMD's 1190 rules).

Table 1 – GPS Data	*Heavy-HD Diesel*	*Medium-LH Diesel*	*Medium-LH Gasoline*
Number of Trucks	*14*	*11*	*6*
Idle Time(min/% total)	*204 / 42.5%*	*163 / 61.2%*	*151 / 54.9%*
Average Speed (mph)	*19.34*	*11.21*	*18.39*
Average Trip (miles)	*48.41*	*19.41*	*16.18*

AQMD Contract # 98114 **May 2001**

Evaluation of the Effectiveness of On-Board Diagnostics II in Controlling Motor Vehicle Emissions

Contractor

University of California, Riverside/CE-CERT

Cosponsors

U.S. Environmental Protection Agency

Project Officer

*F*red *Minassian*

Background

On-Board Diagnostics II (OBDII) technology is designed to monitor vehicle operation and identify malfunctions that could lead to increases in vehicle emissions. OBDII checks are currently being implemented in Inspection and Maintenance (I/M) programs in a number of states throughout the country, with mandatory implementation scheduled for January of 2002.

Project Objective

For this program, 77 OBDII-equipped vehicles with the malfunction indicator light (MIL) illuminated were tested before and after repair to determine whether OBDII can identify emissions problems and whether there is an improvement in emissions performance following repair. Test cycles included the FTP, IM240 and a steady state driving test at speeds of 15 and 25 mph, the same speeds used for the California Acceleration Simulation Mode (ASM) Smog Test.

Technology Description

On-Board Diagnostics II (OBDII) is the newest generation of vehicle monitoring and control technology, designed to identify vehicle malfunctions or deterioration that could lead to increases in emissions. OBDII was implemented on vehicles beginning in 1994 with full implementation required for 1996 and newer model years. The OBDII system includes a number of sensors throughout the vehicle's emissions control system that monitor conditions such as engine misfire, catalyst activity, oxygen sensor deterioration and other potential emissions-related problems.

Status

This project was completed in August of 2001. No significant problems were encountered during the course of the project.

Results

Vehicles were recruited on the basis of having the MIL illuminated with a diagnostic trouble code that could result in increased tailpipe emissions. To find the 77 vehicles utilized in this test program, 147 vehicles were identified and prescanned. Of the vehicles that were excluded, the primary reason was for evaporative problems. The vehicle distribution included domestic and foreign manufacturers, light-duty passenger cars and light-duty trucks with model years ranging from 1995 to 1999. The vehicles were from a California in-use fleet and included 25 Tier 1 certified vehicles, 33 TLEV certified vehicles, 18 LEV certified vehicles, and 1 ULEV certified.

A breakdown of the pre-repair emissions results for the fleet against the FTP certification standard is provided in Table 1. The results indicate that before repair 48 of 77 vehicles, 62%, were found to have emissions below the certification standard and 60 of 77 vehicles, 78%, had emissions below 1.5 times the standard. It is important to note that this does not necessarily indicate that the OBDII systems are operating improperly since for many components the MIL is designed to illuminate when the component is operating outside of it specifications rather than for a specific emissions threshold.

Misfires, bad oxygen sensors and EGR problems were the most common problems in the fleet. Of these the misfires tended to be the most difficult to diagnose. Some of the more significant repairs included replacement of the fuel injection system

and replacement of bad catalysts. Ten of the 77 **test** vehicles either required no repair to extinguish the MIL or had the MIL go out before repair.

Average pre- and post-repair FTP tests results are summarized in Table 2 for vehicles with initial FTP results >1.5 times the certification standard, between 1 and 1.5 times the certification standard, and below the certification standard. Ten vehicles that required no maintenance are not included in this data set. There were also two vehicles that did not get repaired and complete the test sequence. Overall, the data show that relatively significant emissions reductions were obtained from the vehicles with initial emissions >1.5 times the standard. Repairs for vehicles with initial emissions < 1.5 times the FTP certification standard resulted in some measurable but smaller reductions in emissions.

The emissions trends observed for the IM240 test were similar to those seen for the FTP. In particular, significant reductions were found for the highest emitters (>1.5) after repair while some smaller but measurable reductions were seen for the vehicles with initial emissions <1.5 times the standard. Over the two steady state driving speed, on the other hand, the vehicles in each of the emissions categories showed emissions reductions. This could be due to differences in the driving patterns or testing conditions for steady state driving cycle compared with the more transient FTP and IM240.

Benefits

The implementation of OBDII into Smog Check represents a significant change to inspection and maintenance programs throughout the country. OBDII offers many potential advantages over more traditional dynamometer emissions tests. OBDII can provide a more preventative maintenance element to the I/M, provide a more simplified approach for the I/M testing, and may represent the only methodology capable of evaluating I/M issues on newer generation low emitting vehicles. The data obtained here provide an important basis for the evaluation of OBDII systems against more traditional dynamometer emissions tests. These data also provide important information on an in-use California-based fleet that includes advanced technology low emitting vehicles and vehicles operated exclusively on low sulfur gasoline.

Project Costs

Total Funding for this project was $529,000 SCAQMD funding in the amount of $341,000 was provided for this project. EPA co-funding of $188,000 was also provided for this project.

Commercialization and Applications

OBDII has been available commercially since 1994 and has been implemented on all vehicles beginning in 1996. The system is continually being evaluated for improvements, however, and programs such as this are vital to the successful implementation of the technology into production vehicles and national I/M programs. Information from this study will allow the commercial systems to be optimized for sensitivity settings for sensors and other calibrations needed for the best possible performance.

Table 1. Fleet Comparison of FTP Results with Certification Standard

	PC	LDT	Total
> 1.5 times FTP Certification Standard	**11**	**6**	**17**
1.0<X<1.5 times FTP Certification Standard	**12**	**0**	**12**
Below Standard	**31**	**17**	**48**

Table 2. Average FTP Emissions Results Before and After Repair

		# of	THC	NMHC	CO	NO_x
Level		**Vehicles**	**g/mi**	**g/mi**	**g/mi**	**g/mi**
x>1.5 Cert	**Before**	**16**	**1.312**	**1.179**	**14.622**	**0.566**
	After		**0.165**	**0.146**	**2.300**	**0.228**
1.5>x>1	**Before**	**10**	**0.200**	**0.177**	**2.285**	**0.307**
	After		**0.167**	**0.144**	**2.231**	**0.231**
Below Cert	**Before**	**39**	**0.117**	**0.101**	**1.666**	**0.197**
	After		**0.111**	**0.097**	**1.471**	**0.183**
10			**Maintenance Not Required**			

2	**Repair Not Completed**

AQMD Contract #99045 **November 2001**

Demonstrate Fast Response On-Board NOx Sensor for Heavy-Duty Diesel Vehicles

Contractor

Air Resources Board; Southwest Research Institute, subcontractor

Cosponsors

Air Resources Board; AQMD

Project Officer

Mike Bogdanoff

Background

The California State Implementation Plan for Ozone calls for significant reductions in NOx emissions generated by on-road, heavy-duty vehicles. The primary means of achieving these reductions will be through new and optimizing technologies being incorporated on diesel engines. One component under development is a real-time NOx sensor with a response time and accuracy conducive for implementation on engine control systems. The California Air Resources Board (CARB) solicited for this project, and the AQMD was invited to support it.

Project Objective

This project was to select and calibrate two types of fast-response NOx sensors to provide accurate real-time measurement of exhaust gas NOx. These would be demonstrated in on-road, four-stroke heavy-duty diesel engines working under typical operating conditions. In addition, the applicability of the demonstrated NOx sensor technologies would be evaluated for heavy-duty alternative fuel vehicles.

Technology Description

Most modern gasoline and natural gas engines use exhaust gas sensors that determine the amount of oxygen in the exhaust gas (oxygen sensors). This information is then processed by the engine controller to fine-tune the amount of fuel being supplied to engine. Such fuel management allows three-way catalytic converters to reduce exhaust NOx emissions to very low levels. However, this type of sensor is not useful for diesel engines because there is excessive oxygen in diesel exhaust. Sensors that detect NOx have the potential to control fuel injection, exhaust gas recirculation (EGR) and other parameters for NOx control on diesel and other heavy-duty engines.

Southwest Research Institute (SwRI) contacted 25 sensor manufacturers/research entities that could potentially participate in this project, and 21 indicated that they were conducting research and development of exhaust gas NOx sensors. However, only one sensor technology was available for demonstration, a fifth generation prototype sensor from NGK Insulators, Ltd., in Japan.

Four of the NGK combined NOx/Oxygen sensors were tested in the SwRI laboratory on a Cummins M11 330-horsepower diesel engine. Following this testing, two sensors were tested for 6 months in line-haul trucks with Cummins M11 engines. Finally, the sensors were re-tested at SwRI to determine the effects of real-world deterioration on sensor accuracy and response. These sensors were also tested on a Deere 8.1-liter natural gas engine.

Figure 1. NOx Sensor with Power Electronics

Status

The prototype NGK sensors functioned well throughout the program whether in a diesel or natural gas exhaust environment. The factory calibrations needed to be refined for both the NOx and oxygen components of the sensors. The sensors exhibited strong linearity for both NOx and oxygen. All sensors exhibited less than 10 percent measurement error as specified. Laboratory exposure to CO_2, O_2 and unburned hydrocarbons (C_3H_6) interference gases marginally decreased the NOx sensor output.

The project was completed on July 14, 2000, and the Air Resources Board Research Screening Committee approved the final report in Spring of 2001. The final report is on file with complete technical details of the project.

Results

In general, the NGK Insulators combined NOx/Oxygen sensors functioned within their published accuracy limits of +/- 10 percent of reading. The interference gas effects are presently of little concern since the ratios of exhaust gas species are generally constant with diesel engines. However, there may be advanced control algorithms that could suffer from the interference gas effects (for example, the use of selective catalytic reduction [SCR] systems). In the current form, the sensors and power electronics (controllers) cannot be powered by a vehicle battery due to a strict 14.0 +/- 0.5 volts DC requirement. NGK Insulators is currently developing power electronics that are compatible with conventional battery systems.

Benefits

The sensors and controllers evaluated in this project were only prototypes. However, they did demonstrate the potential for such technology to respond and withstand normal in-use exhaust gas conditions. An extended test is recommended to further evaluate the durability of the sensors on a long-term field demonstration. The ultimate benefit of this technology will depend upon the OEM engine manufacturers and their technical strategies for controlling NOx emissions on future engines.

Project Costs

The total cost of this project was $350,000. The AQMD provided $125,000 while the CARB funded the remaining $225,000.

Commercialization and Applications

Only prototype sensors were evaluated and demonstrated under this project. This indicated that NOx sensors have the potential to respond to exhaust gas NOx from both heavy-duty diesel and natural gas engines. However, their ultimate commercialization will depend upon the overall strategies that OEM engine manufacturers employ to control NOx and particulate matter emissions and to improve fuel economy. There are several competing technologies available at this time including SCR, EGR, low-NOx catalysts and sophisticated electronic engine controls.

AQMD Contract # 99120 *August 2001*

Evaluation of the Effects of Biodiesel and Biodiesel Blends on Exhaust Emission Rates and Reactivity -2

Contractor

University of California, Riverside/CE-CERT

Cosponsors

Southern States Power Co, Ontario, CA.

Project Officer

Fred Minassian

Background

Alternative diesel fuels continue to be of interest as important measures in controlling diesel emissions. The present program was designed to further investigate the effects of alternative diesel fuels on exhaust emission rates and composition in comparison with California specification reformulated diesel (CARB).

Project Objective

In this project, an in-use CARB fuel was compared with ARCO's Emission Control-diesel (EC-D) and three 20% biodiesel blends (2 soy-based and 1 yellow grease-based). Chassis dynamometer tests were performed on 7 vehicles using each of the 5 fuels. For these tests, emissions measurements were collected for regulated gaseous emissions and particulate matter (PM). Additional measurements were performed to provide chemical characterization of the exhaust PM including elemental and organic carbon, ions and trace elements and metals, identification of semi-volatile and particulate phase PAHs, and speciation of gas phase C_1-C_{12} hydrocarbons (HCs) and carbonyls.

Technology Description

As the impetus to reduce diesel emissions continues, the need to develop more advanced or alternative diesel fuels becomes more important. Two fuels that are being examined to meet these needs include biodiesel and ARCO Emission Control Diesel (EC-D). Biodiesel is renewable and can be produced domestically from sources such as vegetable oils, animal fats, restaurant grease, or other feedstocks. A number of studies of larger heavy-duty engines and heavy-duty vehicles have shown that biodiesel can provide emissions reductions in HCs, carbon monoxide (CO) and PM, with some increases observed for nitrogen oxides (NO_x). Much of this work has focused on comparisons with Federal diesel, however, with limited studies providing comparisons with California reformulated diesel (CARB).

More recently, ARCO has developed a new diesel fuel called Emission Control Diesel (EC-D). EC-D is produced from typical crude oil using conventional refining processes but is designed to have a sulfur content below 15 ppmw and lower aromatics and a higher cetane number in comparison with typical in-use fuels. The ultra-low sulfur content of the fuel provides a significant added benefit in that the fuel can be used in conjunction with sulfur-sensitive emission control devices.

Status

This project was completed in August of 2001. No significant problems were encountered during the course of the project.

Results

The EC-D and the OXy-G B-60 yellow grease biodiesel blend both showed significant reductions in THC and CO emissions over the test vehicle fleet. THC emission reductions for EC-D compared with CARB fuel were found for 6 of the 7 test vehicles with reductions ranging from 32 to 56%. Five of the seven test vehicles showed THC emission reductions for the OXy-G B-60 biodiesel blend ranged from 21 to 66% compared with the CARB fuel. CO emissions reductions ranged from 12 to 41% for the EC-D and from 0 to 46% for the OXy-G B-60 relative to the CARB fuel. The THC and CO emissions for the soy-based biodiesel blends were comparable over the test fleet to those

of the CARB fuel. NO_x emissions were comparable for the different fuel types over the range of vehicles tested.

EC-D showed the most significant reductions in PM emission rates, with reductions ranging from 5 to 43%. The OXy-G B-60 showed some promise in reducing PM emissions for the highest emitting vehicle, but had PM emissions rates comparable with those of the in-use fuel for the remaining vehicles. The soy-based biodiesel blends had higher PM emissions rates than the in-use fuel for 4 of the 7 vehicles, with comparable PM emission rates for the remaining three vehicles.

Detailed C_1-C_{12} NMOG speciation showed alkenes and carbonyls were the most prominent compound classes in this range. The species distribution as a function of carbon number showed a peak at the C_2 species, which included ethane, ethyne, and acetaldehyde. The four primary toxic air contaminants (formaldehyde, acetaldehyde, benzene, and 1,3-butadiene) composed approximately 15 to 20% of the total organic gases.

Total carbon accounted for more than 70% of the PM mass for 4 of the 5 sampled vehicles. The elemental and organic fractions varied significantly from vehicle to vehicle but showed very little fuel dependence. Inorganic species including ions and elements represented a smaller portion of the composite total, ranging from 0.2 to 3.3% of the total particulate. For each test vehicle, the EC-D had the lowest emission rates for S and SO_4^{2-} consistent with the lower sulfur levels found in this fuel. The soy-based World Energy biodiesel blend also had a tendency for higher emissions rates of elements and ions relative to the other fuels.

Total PAH emissions ranged from approximately 1.8 mg/mi to 67.8 mg/mi over the different vehicle/fuel combinations representing between 1.6 and 3.8% of the total PM mass. For 3 of the 5 vehicles, the EC-D had the lowest PAH emissions. The biodiesel blends generally had emissions comparable to or lower than the RFD fuel

Benefits

The emissions results showed significant improvements for both the EC-D and the OXy-G B-60 yellow-grease biodiesel blend. The EC-D fuel showed emissions reductions ranging from 32 to 56% for THC, from 12 to 41% for CO, and 5 to 43% for PM. The OXy-G B-60 yellow grease biodiesel blend showed emissions reductions of 21 to 66% for THC, from 0 to 46% for CO. The yellow grease biodiesel blend also showed PM reductions for 2 vehicles. The 2 soy-based biodiesel blends showed similar emissions to those of the CARB fuel.

Project Costs

Total funding of $325,000 was provided for this project. SCAQMD provided $300,000 for this project. Co-funding of $25,000 was provided by the Southern States Power Co.

Commercialization and Applications

The EC-D fuel has been used extensively in demonstration programs throughout Southern California. BP ARCO is beginning to produce a more commercial version of this fuel, called EC-D1. This fuel has a sulfur content below 15 ppmw, but with an aromatics content and cetane number more similar to in-use fuels.

In recent years, legislative incentives have rapidly expanded the market for biodiesel fuels throughout the nation. The best performing yellow grease biodiesel from this study, OXy-G B-60, has seen considerable increases in its market-base over the past couple of years and has a major fuel supply contract with the Deer Valley Unified School District in Arizona.

AQMD Contract #99128 **March 2001**

Develop On-Road System for Emissions Measurement from Heavy-Duty Trucks

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

Cosponsors
U.S. Environmental Protection Agency, Detroit Diesel Corp., Caterpillar Inc., Cummins Engine Co., Volvo Truck Corp., Mack Trucks Inc., Navistar International Transportation Corp.

Project Officer
Mike Bogdanoff

Background
Emissions from heavy-duty compression-ignition (diesel) engines are emission certified on engine dynamometers using testing cycles designed to be representative of "real world" operating conditions. It is clear, however, that these testing cycles do not represent all actual operations.

The U.S. EPA and other organizations have developed suitcase-size emissions measurement systems designed to quantify emissions from a heavy-duty truck under actual operating conditions. These systems, however, generally measure only a few gaseous species and report data in parts per million, not grams per mile.

In response to this need, CE-CERT has developed a system to provide "laboratory-quality" emissions measurements from heavy-duty trucks as they operate under actual driving conditions. The system consists of a full complement of emissions measurement instrumentation (including a dilution tunnel) contained within a 53-foot trailer. The laboratory itself serves as the load for a truck. As the truck pulls the trailer, its emissions are captured and quantified just as they would be in a stationary laboratory.

Technology Description
CE-CERT used a 53-foot refrigerated trailer as the platform for this laboratory. Instrumentation includes:

- Flame ionization detector for hydrocarbons and methane.
- Chemiluminescent analyzer for NOx.
- Carbon monoxide detector.
- CO_2 measurement system.
- Secondary dilution tunnels for particulate size and mass analysis, and additional ports for incorporation of enhanced particulate measurement systems.
- Dew point tunnel.
- Pressure detector.
- Global Positioning System.
- Sensors and data collection system for vehicle operating parameters.

All analyzers were tested on a shaker table to assure that they could withstand the noise and vibration inherent in on-road measurements. Side-by-side correlation testing with instruments in CE-CERT's Vehicle Emissions Research Laboratory, using bottled calibration gases and real vehicle exhaust, were performed.

CE-CERT has designed standardized testing cycles to use in the parking lot of the California Speedway and/or on the road to enable repeatable measurements.

Status
Laboratory construction was completed in 2000. While to some extent it will always be a work in progress, with new capabilities or instrumentation being installed, it fundamentally is ready to begin collecting data on the emissions performance of heavy-duty trucks under actual operating conditions. The research plan includes studies of

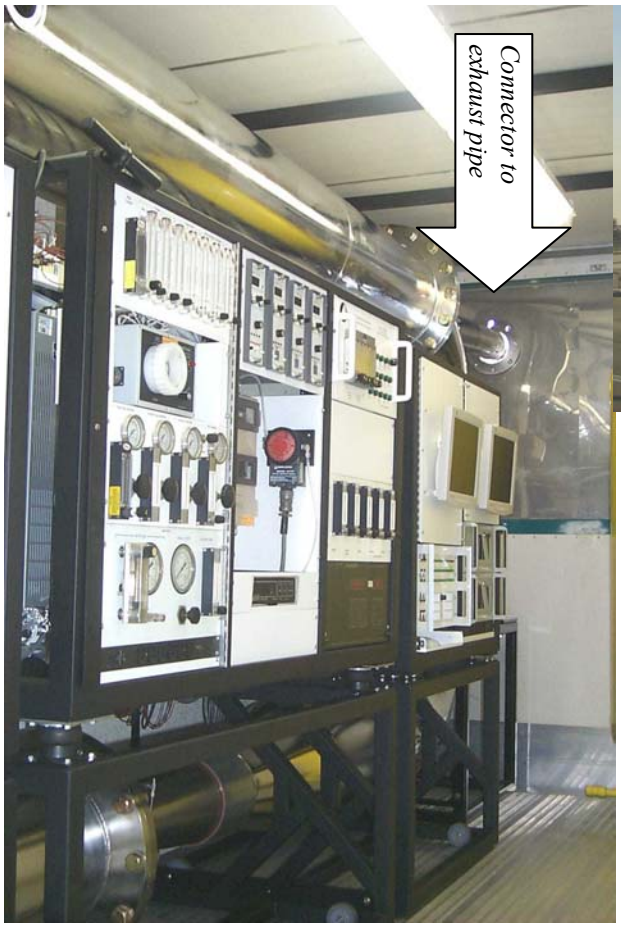
the effectiveness of diesel fuel reformulation, the effectiveness of exhaust aftertreatment technology, the effectiveness of alternative fuels, and the effectiveness of alternative powertrains in reducing vehicle emissions. Data also will be collected for development of a modal emissions model for heavy-duty trucks. Funding toward this end already has been committed by the California Department of Transportation through the UC PATH program.

Performance

Testing determined that it is feasible to make "laboratory-quality" emissions measurements of gaseous and particulate pollutants in this mobile configuration. We also determined that noise, vibration, and motion introduced under on-road operating conditions have an effect on the performance of emissions measurement systems, but measurements of acceptable quality can be made. Repeatable driving cycles that represent "real world" operating conditions and also correlate with standard dynamometer testing cycles can be designed and driven safely and repeatably.

Applications

With support from government agencies and industry, the laboratory will be used to study the effectiveness of reformulated fuels, emission control technologies, alternative fuels, and alternative powertrains in reducing emissions from heavy-duty trucks. It also can be used to study emissions from stationary sources, such as power generation equipment.



Left: Trailer laboratory interior, looking forward. Dilution tunnel travels below, forward, and above analytical instruments. Connector at the front captures emissions as the truck pulls the trailer.

Above*:* Trailer in operation at the California Speedway**.**

Left: Trailer laboratory interior, looking forward. Dilution tunnel travels below, forward, and above analytical instruments. Connector at the front captures emissions as the truck pulls the trailer.

Above*:* Trailer in operation at the California Speedway**.**

AQMD Contract # 99131 **September 2001**

Investigation of Emission Rates of Ammonia and Other Toxic and Low-Level Compounds Using FTIR

Contractor

University of California, Riverside/CE-CERT

Cosponsors

None

Project Officer

Fred Minassian

Background

The contribution of unregulated compounds is becoming increasingly more important in understanding the overall impact of vehicle emissions on air quality. Recently, experimental work has shown that ammonia (NH_3) emissions from vehicles may be more significant than previously thought. This could contribution to increased levels of ammonia nitrate particulate. Nitrous oxide (N_2O) levels are also being investigated since N_2O is a potent greenhouse gas.

Project Objective

The objective of this study is to evaluate and fully characterize the exhaust emissions of a fleet of 10 alternative-fueled vehicles (AFVs). For this test program, 5 CNG vehicles, 3 LPG vehicles, and 2 M85 vehicles were tested over the FTP. Emissions were characterized using standard bag analyses of regulated emissions, Fourier Transform Infrared Spectroscopy (FTIR), and detailed speciation analyses of the hydrocarbons, carbonyls and alcohols.

Technology Description

Alternative-fueled vehicles are considered by many to be an important component of any air quality improvement program. In order to fully understand the impact that AFVs have on the ambient air quality, it is important to have a full characterization of their exhaust species. NH_3 and N_2O emissions have recently been recognized as important emissions due to their contribution to secondary PM formation and the greenhouse gas effect, respectively. It is known that these emissions typically form over the catalyst, and hence, are likely to be found in AFVs as well as more conventional vehicles. The NH_3 and N_2O emissions levels will depend heavily on the control strategies used on different vehicles including fuel control strategies and the catalyst formulations. In order to maintain these emissions at their lowest possible levels, it is important to thoroughly evaluate their formation rates for different vehicle technology systems.

Status

This project was completed in September of 2001. No significant problems were encountered during the course of the project.

Results

The emission results for this study are presented in Table 1. The CNG vehicles and the two newest LPG vehicles all had relatively low NMOG emissions. One LPG vehicle had NMHC emissions above its certification level. The two M85 vehicles had the highest CO emissions in the fleet.

NH_3 emissions for the vehicle fleet averaged 0.124 g/mi for the vehicle fleet with a range from 0.004 to <0.540 g/mi. Excluding the highest emitting vehicle for NH_3 drops the average for the 9 other vehicles to 0.078 g/mi. N_2O emissions averaged 0.022 g/mi over the vehicles fleet with range from <0.002 to 0.077 g/mi. Modal emissions showed that the onset of NH_3 emissions typically occurred after catalyst light-off, near when the catalysts reached their respective equilibrium temperatures. The onset of N_2O emissions typically occurred before that of the NH_3 emissions during the initial stages of catalyst light-off. As the catalysts approached and reached their equilibrium temperatures, however, N_2O emissions generally decreased significantly. The organic gas phase speciation profiles were

consistent for the different fuels of operation used in the testing program. For CNG vehicles, methane made the largest contribution to the total organic gas emissions, representing an average of about 92.5% of the total organic gas emissions with a range from 81 to 96%. Propane was the largest organic gas component for the LPG vehicles, composing between 76 and 82% of their total NMOG emissions. Other species observed in the exhaust for both CNG and LPG vehicles include ethane, formaldehyde, and ethene. Methanol was the largest component for the M85 vehicles, composing 74 to 77% of the total NMOG.

Benefits

This study has provided important information on the exhaust emissions from vehicles fueled in different fuels. Although AFVs in general provide important emissions reductions for regulated pollutants, the AFVs tested in this study still have NH_3 and N_2O emissions levels that are comparable to those of more conventionally fueled vehicles. The results obtained from this study will provide important information on which vehicle configurations are the most susceptible to NH_3 and N_2O emissions. By improving our understanding of these emissions, improved technologies can be developed to reduce these emissions in the near-, mid-, and long-term.

Project Costs

SCAQMD provided $100,000 for this program.

Commercialization and Applications

AFVs have reached the commercial stage and are being considered for large production volumes to help facilitate improvements in air quality and to provide more independent sources for energy. As these vehicles are being produced in larger volumes, it is important have their emissions optimized to provide the maximum possible air quality benefit. To date, little information has been available on the formation of NH_3 and N_2O from AFVs. Since NH_3 and N_2O emissions are becoming a more critical component of overall emissions control strategies, this information will be useful in the development of commercial vehicle applications with reduced levels of NH_3 and N_2O in conjunction with reductions in the more traditionally regulated pollutants.

Table 1. Summary of FTP Emissions Results for the Test Fleet

Model Year	*Make*	*Model*	*Fuel*	*NMOG (g/mi)*	*R-NMOG (g/mi)*	*CO (g/mi)*	*NO_x (g/mi)*	*NH_3 (g/mi)*	*N_2O (g/mi)*
1999	*Honda*	*Civic GX*	*CNG*	*0.005*	*0.002*	*0.252*	*0.026*	*0.021*	*<MDL*
1995	*GMC*	*Sonoma PU*	*CNG*	*0.045*	*0.025*	*1.604*	*0.977*	*<MDL*	*0.022*
1994	*Dodge*	*Caravan Minivan*	*CNG*	*0.015*	*0.007*	*0.464*	*0.200*	*0.005*	*0.008*
1994	*Dodge*	*Ram 350 Van*	*CNG*	*0.059*	*0.032*	*3.329*	*0.913*	*0.116*	*0.077*
1994	*Dodge*	*Ram 350 Van 2*	*CNG*	*0.028*	*0.015*	*1.698*	*0.217*	*0.127*	*0.016*
2000	*Ford*	*F-150 XL*	*LPG Gasoline*	*0.053*	*0.027*	*1.963*	*0.145*	*0.540*	*0.017*
1999	*Ford*	*F250 XLT*	*LPG Gasoline*	*0.037*	*0.019*	*0.355*	*0.420*	*0.078*	*0.012*
1992	*Chevrolet*	*S10 PU*	*LPG*	*0.756[a]*	***0.679[b]***	*0.086*	*0.492*	*<MDL*	*0.006*
1994	*Ford*	*Taurus FFV*	*M85*	*0.836*	***0.343***	***9.074***	***1.108***	*0.120*	*0.059*
1992	*Dodge*	*Spirit FFV*	*M85*	*0.130[c]*	*0.111[d]*	*4.001*	*0.209*	*0.235*	*0.004*

Notes: R-NMOG = reactivity-adjusted NMOG=(measured NMOG)(reactivity adjustment factor) or for CNG vehicles =(measured NMOG)* (natural gas reactivity adjustment factor) + (measured methane) * (methane reactivity adjustment factor) (CARB, 1996)*

a= Total Hydrocarbons as measured by FID b= Non-methane hydrocarbons as measured by FID

c= organic material hydrocarbon equivalent;

d= organic material non-methane hydrocarbon equivalent

***Bold Numbers** = Emissions above the 50,000 miles certification limits for vehicles with < 50,000 miles or above the 100,000 mile certification limits for vehicles with > 50,000 miles.*

<MDL = below detection limits

STATIONARY SOURCES - CLEAN ENERGY TECHNOLOGIES

AQMD Contract # 97130 *December 2001*

Development and Demonstration of a Premixer/Catalytic Combustor Component

Contractor

South Carolina Institute of Energy Studies

Cosponsors

Solar Turbines Inc.; UCI Combustor Laboratory; University of California; and Catalytica Energy Systems, Inc.

Project Officer

Adewale Oshinuga

Background

Catalytic combustion systems represent a potentially significant technology development in low-NOx gas turbine technology. This is especially important in urban air sheds where reducing NOx emissions is vital to improving air quality, and applications of gas turbines are expanding rapidly due to the advance of:

- Combined cycle and co-generation systems
- Distributed power generation
- Future application of ultra high-efficiency combined fuel cell/gas turbine systems
- Future application of gas turbine to rail locomotives
- Future application of gas turbines to hybrid automobiles

Exceptionally good mixing of fuel and air is needed to minimize NOx and minimize hot spots and thermal stresses within the catalyst.

Project Objective

The objective of this program was to develop and demonstrate an optional, low pressure drop premixer capable of delivering highly mixed reactants to the inlet plane of a catalytic combustor under high-pressure ratio conditions.

Technology Description

The catalytic combustor achieves the environmental benefits by exposing pre-mixed fuel and air to a noble metal surface on which the fuel can react with air to induce a flame at leaner conditions than would be achieved by swirl or bluff body stabilization. The challenge is to create the best possible mixing at minimum pressure drop. An ideal premixer would provide a ± 3% concentration and ± 10% velocity uniformity to the catalyst bed. Conventional mixing technology suggested the use of static mixers, however, the project team questioned if the necessary concentrations, and velocity uniformity could be achieved within allowable pressure gradients and equipment space limitations.

Status

This project has been completed, and a final report is on file with AQMD.

Results

Testing results for velocity and fuel/air concentration revealed that the “baseline” mixer did not meet program goals. Approximately six baseline configurations were tested. Through a multitude of 2-dimensional flow visualization studies combined with a wide range of computational fluid dynamics computer models, a novel premixer design was established. The Generation (Gen) 1 Novel Premixer incorporated an involute curved surface through a horseshoe bend to gently, but rapidly accelerate the flow through a throat section. A second involute surface was used to control the expansion from the throat enabling significant pressure recovery and prevent flow separation. The acceleration of the flow through a narrowed “throat section” in the premixer resulted in high turbulent kinetic energy thereby enhancing fuel/air mixing.

The success of the Gen 1 Novel Premixer led to the development of the Gen 2 Premixer, a direct scale down of the Gen 1 hardware. The Gen 2 hardware was first tested at atmospheric conditions at UCI resulting in exceptional concentration and velocity uniformity. The premixer was then mated to a catalyst element and installed in the Solar test rig (See Figure 1).

Figure 1: Solar Turbine High Pressure/Temperature Test Rig

Measurement of the fuel/air mixture concentration uniformity at elevated temperature and pressure was within the desired ± 3% of the mean. The "live fire" test resulted in the catalytic element lighting off and generating a reaction. The results of the solar test were deemed inconclusive. NOx emissions were extremely low and very encouraging. However, the HC and CO emissions were not as expected. This could have been a result of some premixer issues (specifically velocity uniformity) or some rig issues (flow control, non-optimal burn-out zone section).

Benefits

The development of an efficient premixer for catalytic combustor offers significant payoff opportunities. Solar Turbines ATS-S combustion section is designed with the flexibility that it will facilitate the retrofit of the advanced catalytic combustion system. This general approach is common to Solar's entire group of ATS-S engines. These engines will range in size from 300-kW to 15-MW. Furthermore, Solar Turbines is attempting to penetrate the diesel locomotive market. The ATS-S engine at 5-MW (6,700 hp) is in the power range that locomotive users will be targeting in the near future, and it has the efficiency, size, and air quality benefits, and potentially the cost structure to be able to compete with diesel and natural-gas fired reciprocating engines. These advanced gas turbines are also potential candidates for the hybrid electric vehicle market.

Project Cost

The total cost of this project was $977,000, of which AQMD contributed $534,000. Solar Turbines, University of California Irvine Combustion Laboratory, Catalytic Energy Systems and South Carolina Institute for Energy Studies provided the remaining direct cash and in-kind contributions.

Commercialization and Application

The successful demonstration of this unique premix combustor concept will directly impact low emissions and pollution control in Southern California. In addition, it will affect the international market for advanced power generating technologies – which are projected to total one trillion dollars in the next 10 to 20 years. The synergism and collaboration resulting from this strategic alliance will effectively reduce both the risk and cost of this demonstration project and will also facilitate the transition and rapid commercialization of this advanced concept in the worldwide market.

The Novel Premixer design met program goals and is now available for applications. The novel design provided a significant improvement over the "baseline" design that was based on currently accepted mixing techniques for the target engine. The novel design also showed no evidence of undesirable flow separation or flame stabilization within the premixer. The involute horseshoe bend, a necessity for the initial application, was successfully demonstrated as being scalable to two different size injectors representing two distinctly different target engine designs. While the results of the actual rig test were inconclusive, the premixer/catalyst performance was highly encouraging and deemed worthy of further investigation.

STATIONARY SOURCES - VOC AND PM REDUCTION TECHNOLOGIES

AQMD Contract #99143 *December 2001*

Development and Demonstration of Zero- and Low-VOC Resin Technology for Advanced Control Measure Development

Contractor

AVES, an affiliate of ATC Associates, Inc.

Cosponsors

Adhesives Coatings Co. (ADCO).

Project Officer

Abid Latif

Background

The 1997 AQMP control measure "Long Term Control Measure for Architectural Coatings" (CM#97ADV-ARCH) required an additional 25% VOC emission reductions from architectural coatings. The control measure called for the development of zero-VOC architectural coatings in certain large volume categories. Staff identified stains, sanding and waterproofing sealers, and clear wood finishes as large volume categories, which contributed up to 7.8 tons per day of VOC emissions, according to the 1999 California Air Resources Board (ARB) survey of 1996 coating sales. The emissions from these categories will be reduced to 4.4 tons per day after all future VOC limits in Rule 1113 (Architectural Coatings) are implemented.

Project Objective

The objective of the project was to develop, test, and demonstrate zero- or low-VOC lacquer, varnish, exterior opaque stains, exterior and interior semitransparent stains, sanding sealers, waterproofing sealers for wood and concrete and masonry.

The purpose of the laboratory tests and field demonstration was to evaluate the physical properties and performance characteristics of all new formulated coatings on various substrates and compare them with the performance of existing coatings commercially used by the industry today. Another project objective was to compare the cost and environmental impacts of the new formulated coatings with the existing coatings.

Technology Description

RESILEX, a resin emulsion in water, was the base material used to formulate the new low-VOC coatings. This no-VOC resin system, invented and patented by ADCO, was engineered as the next step beyond conventional water-based emulsion systems. RESILEX is a colorless, odorless, and VOC- and hazardous air pollutant (HAP)-free resin system that can be used as a resin system alone, in combination with water-based lattices, or as an enhancement in latex paint formulations to provide greater durability. This resin system was also used to develop and demonstrate a zero-VOC metal coating system through the Innovative Clean Air Technology (ICAT) program of ARB in the late 1990s.

Status

The contract with AVES was executed on June 30, 1999. The formulation, small scale laboratory testing, and the field demonstration were successfully completed. The contract was terminated, however, because the contractor failed to meet contractual requirements and proposal commitments.

Results

The newly developed coatings were tested for their performance and VOC content. The tests were divided in the following categories:

- VOC Determination.
- Comparative Performance Properties
- Comparative Repair/Refinishing
- Field Demonstration

Analysis by Gas Chromatography and mass spectroscopy (GC/MS) method confirmed that the VOC content for all new coatings were less than 10 grams per liter.

Most performance characteristics of the new coatings were equivalent to those of waterborne and solvent-based coatings commercially used today. However, some of the new coatings were not found to be as good as solvent-based coatings relative to some properties such as dry time, freeze/thaw, mildew/fungus resistance, pot life, print resistance, and stain blocking.

Three popular commercially-available coating systems (both lacquer and varnish) were tested side-by-side with newly formulated lacquer and varnish topcoat systems for repair and refinishing. The new varnish system showed the best overall appearance after repair, but had the highest coating usage due to short pot life of the two-component system. The new lacquer system was the easiest to repair and showed the best gloss after repair.

Impartial and experienced painters, who conducted the field testing of the new coatings, were very satisfied with the performance of the new coatings.

Benefits

If the use of the new coatings is successfully implemented, the future VOC emissions of 4.4 tons per day from these categories will be reduced to approximately 0.5 tons per day, which corresponds to an additional emission reduction of 3.9 tons per day.

Project Costs

The total cost of this project was $557,500.with AQMD contribution not to exceed $185,000. The actual expense to AQMD was $150,000.

Commercialization and Applications

The overall performance of new coatings has been demonstrated to be satisfactory. One of the effective ways to commercialize these coatings is to include the implementation of this technology in the future amendments of Rule 1113.

TECHNOLOGY TRANSFER AND ASSESSMENTS

AQMD Contract #99134 **August 13, 2001**

Cosponsor School Electric Vehicle Outreach Effort

Contractor
California State University, Los Angeles

Cosponsor
AQMD

Project Officer
Lisa H. Mirisola

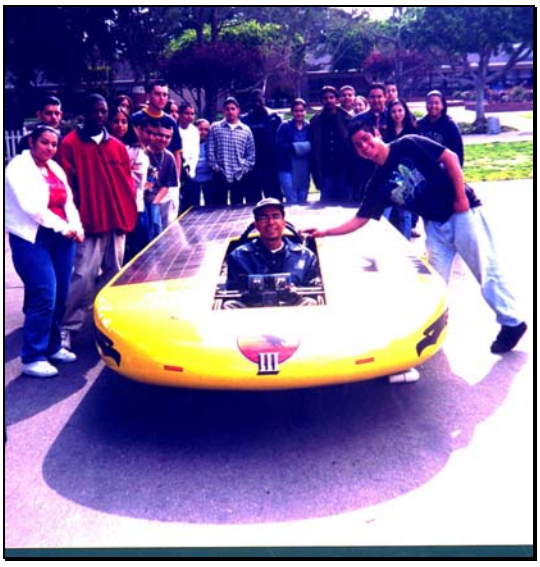
Background
The Co-sponsor School Electric Vehicle Outreach Effort consisted of a visitation program featuring a solar car named Solar Eagle III, which became national champion at the prestigious Sunrayce 97. It also included a mentor program and a solar cell energy curriculum unit implementation program, both for high school students.

Project Objective
The objective of the Solar Eagle III visitation program was to illustrate the possibilities of alternative fuels-particularly solar cell (photovoltaics) generated electricity-discuss the role engineers can play in future development of zero-emission transportation, introduce students to the fields of engineering and technology, and address air quality issues. The objective of the mentor program was to assist high school student teams with designing and building experimental solar-powered or electric vehicles. The objective of the curriculum unit implementation program was to present science and mathematics high school teachers with an opportunity to introduce students to the theory and applications of solar cell energy.

Technology Description
One goal of the outreach effort was to educate students and community members about the benefits and possibilities of renewable energy sources such as solar cell energy. During the presentations, we used the Solar Eagle III as a demonstration tool to explain the technology. Participants asked many questions related to solar cell energy and its practicalities. In addition, participants received AQMD brochures with information on air quality.

Through the mentor program, high school teams had an opportunity to learn more about solar-powered and electric vehicle technologies.

Status
Program goals were successfully implemented and completed by June 30, 2001. Below is a picture that illustrates a typical setting during a Solar Eagle III visitation.



Solar Eagle III at Arroyo High School in Temple City

Results
During the course of the project, about 13,000 participants took part in the Solar Eagle III presentations. We also mailed out about 120 copies of the solar cell energy unit to science and mathematics teachers from local high schools. Lastly, we advised four high schools in designing and building experimental solar-powered or electric vehicles.

Benefits

The benefits of the outreach effort were educational. As a result of this, students and community members became more knowledgeable about renewable energy sources, zero-emission technology, and the need for cleaner air in the South Coast basin.

Project Costs

The actual cost of the project is estimated at $95, 108, which is within the budgeted amount of $97,582.

Commercialization and Applications

An objective of the outreach effort was to demonstrate the application of solar cells through the presentation of the experimental solar car, Solar Eagle III. In addition, through the mentor program, participants became more knowledgeable about the possible applications of solar-powered and electric vehicle technologies.

AQMD Contract #00194 *August 2001*

Evaluation of Battery Operated Emergency Roadside Lighting Devices

Contractor

The City of Claremont Police Department

Cosponsors

N/A

Project Officer

Abid Latif

Background

In an effort to identify alternative roadway emergency and early warning lighting devices that would provide a lighting source that was safer for public safety personnel and the general public, and that reduced the amount of pollutants released into the environment, when compared to traditional flares/fuses, the Claremont Police Department entered into a joint study with the South Coast Air Quality Management District (SCAQMD).

Project Objective

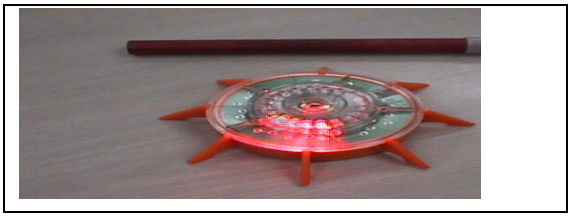
The objective of the project is to use the battery-operated systems for six months and collect sufficient data to decide if the use of traditional flares could be reduced or eliminated and replaced by the battery-operated systems. During the course of the project, information was gathered relative to the effectiveness of the battery-operated systems in different environments, number of times the systems were used, and their safety features. This information was used to compare the air quality benefits, affordability, and safety aspects of the battery-operated systems with that of traditional flares.

Technology Description

The Turbo Flares are alternative lighting devices consisting of bright light emitting diodes (LED's) powered by rechargeable batteries. The LED's are housed in high impact plastic star shaped discs that are able to withstand the weight of vehicle being driven over them, and are resistant to damage from chemical spills. Traditional flares/fuses are an incendiary device that emits chemicals into the air as it burns.

Status

The study of the Turbo Flare was started in November 2000 and concluded in May 2001 (The final report is on file with complete technical details of the project).



Results

The Turbo Flare units were deployed at 42 incidents during the 6-month study. The units were used during the day and night, during rain and wind. They were used for collisions on surface streets, at intersections and on the freeway. They were also used in the down town area for traffic control for three cruise nights. 348 units were deployed for a total of 86 "at scene" hours and 898 hours of actual use (3 units for 2 hours = 6 hours of use). In comparison to traditional chemical flares, it would have required 2,768 flares for the same coverage.

The only drawback to using the Turbo Flares is that they do not work well during the daylight hours. Because of their low profile and lack of brightness during the day, motorists had a hard time seeing the deployed units.

Benefits

The Turbo Flares are easy to deploy and retrieve at the scene, they do not emit pollutants, which can damage the environment or cause an

inhalation hazard to emergency personnel. During nighttime deployment, the rotation of the LED lights cause motorists to see the flare pattern much faster than traditional flares. Drivers can alter their driving to allow for the upcoming incident or move to another lane to safely bypass the incident. The Turbo Flares do not emit any type of spark, which allows the units to be used at chemical spills of flammable or unknown substances, without risk of fire. The Turbo Flare is constructed of Suryln resins, which is chemical resistant. The Turbo Flare is impact resistant to vehicle running over them. A traditional chemical flare would be snuffed out if run over; the Turbo Flare would continue to work.

During this 6-month study, it was determined that the pay-back period for the sixteen Turbo Flare units was 3.24 years with a savings of $4,797 over the life expectancy of the Turbo Flare units.

Project Costs

AQMD funded the entire purchase of the sixteen Turbo Flare units for $7,200.00. The Claremont Police Department funded $2,256.00 for installation of the units, training of personnel, and for evaluation of the product.

Commercialization and Applications

The Turbo Flare units could be used by law enforcement and fire departments as emergency lighting and early warning systems. The Claremont Police Department can cut the use of chemical flares for almost all nighttime deployment. Turbo Flares are currently on the market and are being used by Henderson Police Department, Las Vegas Metro, Manhattan Beach Police and Fire and several other police departments in California, Nevada, and Arizona.

AQMD Contract #01218 **September 2001**

Co-sponsor Los Altos High School Solar Vehicle

Contractor
Los Altos Academy of Engineering, Los Altos High School

Cosponsor
AQMD

Project Officer
Lisa H. Mirisola

Background
The Los Altos Academy of Engineering has a nine-year history of design and construction of clean air competitive vehicles.

Project Objective
In 1996, Solar Shadow I, completed the World Solar Challenge in Australia (1900 miles) with an average speed of 32.08 km/hr (19.93 mph). The World Solar Challenge was a relatively flat course with the highest point at 1500 feet and only one stop light during the entire course. The inaugural American Solar Challenge was a demanding race with the hundreds of stoplights and the highest elevation at 7200 feet. Our objective was to finish this rigorous course with a faster average than the World Solar Challenge.

Technology Description
The technology improvements since the World Solar Challenge have dramatically increased the performance of our solar vehicle, Solar Shadow II. Improvements included a lower coefficient of rolling resistance, Crr, through the upgrade of solar car tires with a Crr of 0.004 versus 0.007 for bicycle tires. In order to incorporate a roll bar and pickup points for adjusting the alignment, the chassis was changed from a strong composite to tubular steel. The addition of a wheel motor raised the overall drive efficiency from 80% to 92%.

One major deficiency was the degrading of the solar array used in the World Solar Challenge. The new array in Australia achieved a maximum output of over 900 watts. The same array, six years later achieved only 800 watts maximum during the race.

Status
Solar Shadow II completed the American Solar Challenge on July 25, 2001 finishing the race in Claremont, California. Initial concerns were about the climb over the western mountains; however, the stops and stoplights in the east were more of a problem. The minimum speed on highways was 40 mph. These speed constraints allowed driving only six hours per day at 40+ mph rather than 10 hours at 30 mph.

Results
In the World Solar Challenge the vehicle average speed was 32.08 km/hr (19.93 mph) while in the American Solar Challenge the average speed was 38.3 km/hr (23.83 mph). The length of the American Solar Challenge was 1602 miles. The low coefficient of rolling resistance tires had one drawback; the high pressure tires were more sensitive to road debris, which caused nine flat tires. The Solar Shadow II was the only high school entry to finish the race along with 30 other universities, placing 22nd with an elapsed time of approximately 121 hours.

Benefits
Building the vehicle allowed students to explore and apply new technologies, and better understand their reduced impact on the environment.

Project Costs
The construction of Solar Shadow II was under $40,000, including AQMD cosponsorship of $5,000.

Commercialization and Applications
New motors have proven their ability to climb on grades as steep as 6%. Currently, no electric vehicle marketed is running on wheel motors. Wheel motors provide a viable drive system for electric vehicles because of their efficiency and torque.