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California clean air initiatives – the role of fuel cells

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Abstract

The interaction between energy and the environment has been recognized for some time, but increasing focus is being placed on the feedback mechanisms between the two as local/regional and federal governments address the issue of regional pollution and global climate change, respectively. In Los Angeles the continued severity of the air pollution problem has stimulated renewed efforts to significantly curtail emissions to meet the health-related air quality standards. This paper provides an overview of the ambient air quality in Los Angeles, the impact of previous emissions control strategies, and the additional reduction in emissions required to meet the health-related air quality standards (Air Quality Management Plan, 1991) The paper focuses upon the role of clean technologies such as the fuel cell to effect the emissions reductions required. Finally, there is a discussion of the demonstration programs, planned or underway, with fuel cells and related technologies in the South Coast Air Quality Management District (SCAQMD), followed by some comments on the regulatory and legislative actions underway to stimulate new technologies.

Background

The SCAQMD is an area of Southern California of approximately 13 350 sq. miles occupied by 13 million people and just under 9 million vehicles. This area encompasses the Counties of Los Angeles, Orange, Riverside and the non-desert portion of San Bernardino. It can be seen from Fig. 1 that the health-related air quality standards are violated by a significant amount for ozone, carbon monoxide (CO) and fine particulates (PM_{10}). This area remains the only one in the US which currently exceeds the air quality standard for nitrogen dioxide. It should be noted that because of the stringent controls on sulfur levels, largely through controlling sulfur in fuels and by encouraging natural gas for electricity generation, the District does not experience a problem with SO_2 air quality. Although the SCAQMD is in non-attainment for most of the criteria pollutants, previous emission controls have been effective in improving air quality in the region. Even for the most ubiquitous air pollutant, i.e. ozone, there has been significant improvement during the last several years. For example, Table 1 shows cumulative daily ozone station hours for the last 12 years at the majority of monitoring stations in the Basin. The data show that during the period 1980–1990 the hours over the standard of 0.12 ppm have been reduced by about one third, and the number of hours over the first-stage health alert level of 0.2 ppm have been reduced by an order of magnitude. It should be pointed out that the dramatic improvement over the last year appears to be largely due to favorable meteorology, because emissions reductions occur more gradually and do not take the

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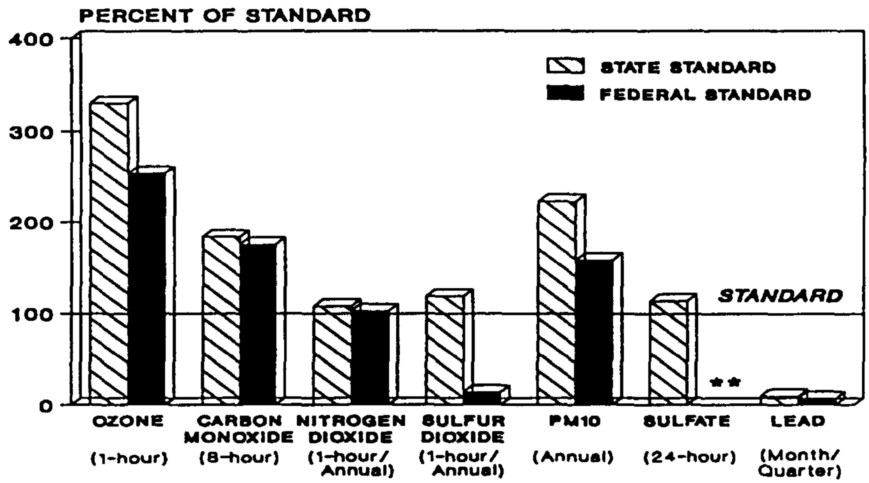

Fig. 1. 1990 Maximum pollutant concentrations as percent of state and federal standards.

TABLE 1

Cumulative daily ozone station hours Jan. 1–Dec. 31, 1990

Year	Ozone concentration thresholds (ppm)				
	0.13	0.20	0.25	0.30	0.35
1990	3457	214	21	2	0
1989	5200	529	74	9	0
1988	6041	638	94	5	1
1987	5314	468	37	1	0
1986	6302	847	109	6	0
1985	7240	1150	242	37	4
1984	6997	1085	201	15	0
1983	8087	1657	405	70	6
1982	6177	977	231	35	7
1981	8606	1505	321	53	7
1980	8927	2399	765	197	43

quantum change that has been exhibited in the air quality data during this time period. However, in order to continue the improvement in the face of continued significant growth in population, additional stringent emissions controls will be necessary [1].

The current emissions inventory for the SCAQMD is shown in Table 2. This gives an approximate breakdown, by broad sectors, of the stationary source and mobile source emissions. The data in Table 2 show that mobile and stationary sources contribute about equally to the reactive organic gas (ROG) inventory, while mobile sources dominate the emissions of nitrogen oxides (NO_x) and CO. Further breakdown of the inventory shows that fuel combustion comprises the major portion of the stationary-source emissions of nitrogen oxides (NO_x).

The 1987 mobile-source inventory has been updated to take into account evaporative emissions, both diurnal and hot soak, as well as running losses from light-duty motor

TABLE 2

Summary of emissions by major source category: 1987 base year[a], average annual day (tons/day)

Source category	ROG	NO_x	CO	SO_x	PM10
Stationary sources					
Fuel combustion	17	267	78	23	14
Waste burning	1	2	3	0	1
Solvent use	464	0	0	0	1
Petroleum process, storage and transfer	107	9	6	19	3
Industrial processes	41	12	7	8	45
Miscellaneous processes[b]	57	1	5	0	942
Total	687	291	99	50	1006
Mobile sources					
On-road vehicles	605	664	4363	32	53
Off-road mobile	83	253	525	52	16
Total	688	917	4888	84	69
Total	1375	1208	4987	134	1075

[a]The emissions used to track the 5% requirements will be based on planning inventories, per ARB requirements.
[b]Travel-related road dust included.

vehicles. These emissions were not recognized earlier and provide additional impetus to develop low-emission technologies for automobiles. There continues to be concern about the overall accuracy of the emissions inventory, specifically that it is underestimated, particularly for ROG and CO.

Recent computer modeling has indicated that in order to meet the health-related air quality standards, NO_x, ROG and CO reductions of approximately 80% will be required by the year 2010. The most perverse pollutant is ozone. Control of ozone requires reduction of its precursors, NO_x and ROG, but the interaction of these is highly complex [2, 3]. Sophisticated computer models are needed to understand the impact of emissions reductions on ambient ozone. Our recent Air Quality Management Plan [1] estimates that an 88% reduction of ROG and a 70% reduction in NO_x from 1985 emission levels will be required to attain the Federal Air Quality Standards by 2010. It should be noted in this context that the health data related to ozone exposure continues to indicate that the current ambient air quality standard for ozone may not be adequate to protect public health. For example, a team of scientists from the University of Toronto recently reported [4] that relatively low levels of ozone, i.e., 0.12 to 0.16 ppm, can have a deleterious effect in promoting asthmatic attacks. The bottom line is that the stringent emissions reductions predicted by the model are likely to be a conservative estimate of the reductions needed to meet the air quality standards and protect public health. The magnitude of these reductions requires substantial technical and societal changes. The technical measures being considered are briefly described in the next section.

Measures being considered to curtail emissions

Full documentation of the emission reduction measures being considered to effect the emissions reductions required are provided in the recently released Air Quality

Management Plan (AQMP) [1]. A brief summary will be provided here of some of the key measures being enacted or being considered to effect these reductions, with emphasis on those which have potential for application in the fuel cell area. The discussion is broken down to separately consider mobile sources and stationary sources.

Stationary-source control measures

Stationary-source control measures are aimed at point-source and area-source emissions. Point-source emissions are at facilities with an identified location, such as power plants, refineries or industrial boilers. There are approximately 50 000 point sources in the Los Angeles Basin. Area-source emissions are from small facilities, pieces of equipment, or other sources with locations that are not specifically identified, such as household products. Surface coatings and solvent use contribute the majority of stationary-source ROG emissions in the Basin. Other sources include petroleum and gas production, commercial and industrial processes, residential and public sectors, and agricultural processes.

Stationary-source NO_x emissions contribute a total of 267 tons/day or 22% of the total NO_x inventory, based on 1987 inventory data. These stationary sources have been identified in the AQMP for basic control implementation and a number of rules have been adopted to control combustion-generated NO_x emissions from specific stationary sources. Current District rules and regulations limiting NO_x emissions include the following:

Rule 1109	refinery heaters and boilers
Rule 1110.2	stationary internal combustion engines
Rule 1121	residential water heaters
Rule 1134	stationary gas turbines
Rule 1135	electric power generators and boilers
Rule 1146	industrial boilers, heaters and steam generators
Rule 1146.1	small boilers and heaters

The AQMP has also identified NO_x control measures to be adopted for petroleum refinery fluid catalytic cracking (FCC) units, afterburners, metal melting furnaces, glass melting furnaces, curing and drying ovens, cement kilns, swimming pool heaters, miscellaneous combustion sources, and implementation of additional controls on currently regulated sources.

Fuel cells could find applications to reduce many of these sources of NO_x, including power generation in both large-scale utilities and domestic applications. In each case, emissions could be cut substantially. For example, their use could be part of a utility's demand-side management program, with the excess of on-site electricity generated being sold back to the utility company. The best application of fuel cells would incorporate co-generation to make use of waste heat and by-product potable water. Table 3 shows a broad overview of some of the stationary-source emissions control strategies being considered, together with our indication of the potential for fuel cell introduction. As discussed later, when we consider District-specific demonstrations, fuel cells have significant potential in the areas of commercial and residential power generation.

Mobile-source control measures

Emissions from motor vehicles have been controlled for a number of years and the vehicle exhaust emissions standards have been reduced drastically. Table 4 shows

TABLE 3

Stationary emission reduction strategy

Control method	Source category					
	Surface coating/ solvent use	Petroleum/ gas production	Industrial/ commercial processes	Residential/ public	Agriculture	Other sources
Reformulation	X					
Higher transfer efficiency	X					
Process improvement/modification	X	O	O		O	
Add-on controls	X	X	X	X		
Alternative coating methods/solvents	X					
Alternative fuels		O	O			
I/M programs		X				
Combustion modification			X	X		
Energy conservation			O	O		
Paper/glass recycling			X			
Industrial effluent discharge limits				O		
Phase-out of fuel oil and solid fossil fuel						O
Emission minimization management plan						O
Marketable permit program						O
Emission charges	X					
Waste minimization	X					
Vapor recovery system		X				
Improved vapor recovery		X				
Utility engine refueling operations		O				
Improved fuel shut-off mechanism		X		X		
Out-of-basin waste treatment				O		
Solar collectors				X		
Road dust suppression				X		
Alternative formulation/application methods					O	
Alternative disposal methods					O	
Best available retrofit control technologies						O
Low-emitting construction materials/methods						X
Watering at construction sites						O
Windbreaks						X

X = existing AQMD control, O = existing control, fuel cell potential.

TABLE 4

Automobile exhaust emission standards (g/m.) for HC, CO and NO_x (national) [5]

Model year	HC emissions	CO emissions	NO_x emissions
Uncontrolled	8.2	89.5	3.4–4.4
1968	6.2	51.0	
1970	4.1	34.0	
1972	3.0	28.0	
1973	3.0	28.0	3.1
1975	1.5	15.0	3.1
1977	1.5	15.0	2.0
1980	0.41	7.0	2.0
1981	0.41	3.4	1.0

the decline in the US federal standards. Because of the severity of the air pollution problem in Los Angeles, California is the only state allowed by the federal government to set its own vehicle emissions standards. These are set by the California Air Resources Board (CARB).

The agencies in California were the first to seriously explore the use of cleaner-burning alternate fuels as a way to both improve air quality and decrease the dependence on foreign oil supplies. Spearheaded initially by the California Energy Commission (CEC), methanol has received the most attention of the alternate fuels and many demonstration programs are underway in both the light-duty, heavy-duty, and bus transit applications. These demonstration programs are run by the CEC, CARB and the SCAQMD. Other fuels seen to have emissions reduction potential are natural gas, propane and ethanol, in addition to electricity. In addition to the use of cleaner-burning fuels, including reformulated gasoline, stricter tail pipe standards are required.

The new California LEV/CF program

Continuing its trend in setting technology-forcing standards, the CARB adopted its low emission vehicle/clean fuel (LEV/CF) program, which includes the world's most stringent emissions standards for new passenger cars and medium-duty vehicles. This program is having a dramatic impact on the automobile industry in the US and worldwide. The new California standards address the key interrelated problems of increasing urban smog, declining oil reserves and the changing global environment, since they assume that the introduction of cleaner-burning alternate fuels will be required to a certain extent to meet the stringent standards. Nonetheless, they are projected to have a cost-effectiveness well within the range of previously adopted control measures as a function of in-use mileage.

Working closely with the CEC and the District, CARB developed an innovative approach that phases in fleet-average standards for new motor vehicles sold in California beginning in 1994 [6]. It is revolutionary in concept because for the first time, motor vehicles and their fuels are treated as a single, integrated system. The simultaneous development of advanced vehicle technologies and cleaner-burning fuels is being encouraged by this regulation. Indeed, the current auto/oil program represents a successful joint effort by the automobile and oil industries to develop a system with fewer emissions [7].

The true importance of CARB's regulatory action is that it goes beyond the internal combustion engine by promulgating mandatory sales of zero-emission vehicles (ZEVs). (ZEVs are defined as vehicles that do not directly emit any regulated pollutants.) The various categories of emission standards are shown in Table 5.

As a result of the CARB ruling, over the next five years we expect to see the commercialization of dedicated, optimized, clean-fueled vehicles. Manufacturers may also elect to meet CARB's tightening corporate-average emission standards by producing and selling hybrid EVs with small, range-extending engines to recharge battery packs.

As shown in Table 6, 1998 will mark the beginning of the all-electric automobile era in California. In that year, the state regulations call for a mandatory 2% production of ZEVs, estimated to be 40 000 vehicles. Within another five years, at least 10% of California's new passenger cars (approximately 200 000 vehicles) must be ZEVs. The ZEV definition effectively means that they must be propelled solely by non-combustion power sources, such as batteries or fuel cells. The emissions benefits of ZEVs will be immediate and lasting. Unlike even the cleanest combustion engine vehicles, the air quality benefits of ZEVs never diminish, since their emissions cannot increase as a function of in-used mileage.

TABLE 5

50 000 Mile certification standards (g/m.) for passenger cars operating on gasoline [6]

Category	NMOG[a]	CO	NO_x
Adopted for 1993	0.25	3.4	0.4
TLEV	0.125	3.4	0.4
LEV	0.075	3.4	0.2
ULEV	0.040	1.7	0.2
ZEV	0.0[b]	0.0[b]	0.0[b]

[a]NMOG emissions would be reactivity adjusted for cleaner-burning fuels.
[b]Tailpipe emissions.

TABLE 6

Implementation rates for conventional vehicles, TLEVs, LEVs, ULEVs and ZEVs used to calculate fleet average standards for passenger cars (%)

Model year	0.39	0.25	TLEV 0.125	LEV 0.075	ULEV 0.040	ZEV[a] 0.00	Fleet average standard
1994	10	80	10				0.250
1995		85	15				0.231
1996		80	20				0.225
1997		73		25	2		0.202
1998		48		48	2	2	0.157
1999		23		73	2	2	0.113
2000				96	2	2	0.073
2001				90	5	5	0.070
2002				85	10	5	0.068
2003				75	15	10	0.062

[a]The percentage requirements for ZEVs are mandatory.

Upon reflection, the CARB regulation introducing ZEVs would have been inconceivable just a few years ago. Why the change? A number of factors made major contributions. These factors include:

- the continuing adverse air quality in California and the role of automobile emissions in contributing to this unhealthful condition
- the growing disillusionment among air quality regulators with the conventional internal combustion engine and the frustrations of eliminating in-use tail pipe and non-tail pipe emissions
- the desire by energy officials to establish independence from foreign oil sources
- the need to encourage the auto and oil industries to work closely together, in effect treating the vehicle and its fuel source as a single system
- the growing public concern about global climate change

The regulations also effect the tremendous progress made by the automobile industry in reducing emissions. This, in turn, has led to confidence on the part of regulators that the automobile industry can meet the challenges of the new emission reduction requirements.

In a recent action associated with the District's AQMP, an amendment to the plan to set a goal of 200 000 EVs by the year 2000 in the SCAQMD was introduced by two Board Members, Mr Marvin Braude and Dr Larry Berg. This action puts additional onus on the District to accelerate the introduction of EVs. Councilman Braude, who introduced the Los Angeles Electric Vehicle Initiative in 1988, was one of the first to recognize the need for clean vehicles in meeting the air quality goals in Southern California. The Braude Initiative, as it is commonly known, will attempt to place 10 000 hybrid EVs on the road in Southern California by 1995. The major work is being performed by Clean Air Transport (CAT) of Sweden, in conjunction with International Automotive Design (IAD) of U.K.

In addition to the ZEVs powered by batteries, it is recognized that vehicles powered by fuel cells can also qualify as zero-emission vehicles. This would be the case for hydrogen carried on board, and it is possible that the emissions from an on-board reformer to produce hydrogen would be essentially zero. Fuel cell cars have many advantages, such as:

- greater efficiency
- pollution free (using H_2), or nearly pollution free (using a methanol reformer)
- no toxic pollutants
- no need to control hydrocarbon reactivity
- can use renewable sources of energy
- lower CO_2 emissions and hence smaller impact on global climate change

In a recent study DeLuchi and co-workers [8] show that fuel cells in vehicles provide major energy security and environmental advantages, and may indeed compete with gasoline-based internal combustion engines on a life-cycle cost basis. For example, the authors estimate that a fuel cell vehicle utilizing an on-board methanol reformer could be cost effective with a conventional gasoline engine with gasoline selling in the range of $1.1–$1.4/gallon. For hydrogen, the numbers are $1.5–$1.7/gallon, depending on the gasifiers used for biomass gasification.

Consideration of global environmental problems

As mentioned above, the growing concern with global environmental problems is a major force driving the continuing goal to ultra-low and zero-emitting processes.

The two major global environmental issues addressed by our AQMP are global climate change and stratospheric ozone depletion. Both of these can affect the District's effort to achieve compliance with the air quality standards. Specifically, increases in global temperature and ultraviolet radiation reaching the ground will increase the smog-forming potential of the Basin and interfere with the effects to achieve the air quality standards for ozone and potentially PM_{10}.

Recognizing the importance of the issues, the District's Board adopted a 'Policy on Global Warming and Stratospheric Ozone Depletion' in Apr. 1990. The main components of the policy, which direct efforts to control emissions of both CO_2 and stratospheric ozone depleting compounds, are given in the AQMP [1].

Since adoption of the Policy, the District has taken actions to implement its provisions. Among these are the development of two recycling regulations; the development of the 1991 AQMP control strategies to reduce emissions of carbon dioxide and methane; the development of an emissions inventory for global-warming and ozone-depleting gases; and direct funding of research aimed at the development of alternative substances and processes.

Opportunities for fuel cells

Based on the substantial emissions reductions required in the SCAQMD, as described in the above discussion, it is clear that technologies will be required which have significantly reduced emissions of all gases, including global warming gases. As a result, it is necessary to identify the appropriate type of technologies that can be employed in the Basin and to demonstrate whether these would work for specific applications. It is for this reason that the Governing Board of the SCAQMD set up the Technology Advancement Office (TAO) in 1988. The TaO is charged with looking worldwide to identify advanced emission control technologies, and then to demonstrate those technologies in the SCAQMD area to ascertain the appropriateness of the technology in terms of emission controls and cost effectiveness. The TAO supports cost-shared work in the development of advanced emissions control technologies and cleaner-burning fuels. Now in its third year, this program is an integral part of the District's revised AQMP. A wide range of research, development and demonstration projects are supported, involving cleaner fuels and advanced air pollution control technologies. The aggregate TAO program now approach 100 projects totaling more than \$50 million, consisting of approximately \$15 million in District funds, with the remaining funds provided by industry, other regulatory agencies, research institutes, and various other sources. In total, the TAO leverages about \$3 from outside sources for every \$1 invested by the District. The program is described in more detail in ref. 9.

As part of the demonstrations, the TAO has outlined and is following a program to encourage the demonstration and use of fuel cells. This is a logical progression to the greater use of methanol and natural gas, both of which are good precursors for the hydrogen required in the fuel cells. Because of their inherently increased efficiency and lower polluting capability, fuel cells are very attractive as a means of addressing the emissions reductions necessary to meet the air quality standards [10, 11]. In addition, programs are also underway to generate hydrogen for fuel cell use [12]. Of the various possible fuel cell types – proton exchange membrane (PEM), also referred to as solid polymer electrolyte), phosphoric acid, molten carbonate, solid oxide and alkaline – the District supports demonstration programs which utilize the first three fuel cells.

Stationary-source applications

Commercial buildings

The District is working in conjunction with our local gas utility, Southern California Gas Company, on two projects using phosphoric acid fuel cells with two different vendors. At the new District headquarters in Diamond Bar, California, a 200 kW fuel cell, produced by International Fuel Cells of Connecticut (IFC), will be installed to provide partial power. In addition, a second fuel cell, built by Fuji Electric Company of Japan, with an output of 50 kW, will be utilized. Both of these will use reformed natural gas as the source of hydrogen. Based on measurements from the Fuji fuel cell in Japan, the emissions will be low, as shown in Table 7. Similar emissions levels are expected for the IFC fuel cell.

Residential

The District has recently entered into an agreement with Rolls Royce of America and Johnson Matthey, Inc., together with Southern California Gas Company, to design and test a small-scale fuel cell suitable for residential use. This will be a proton exchange membrane (PEM) fuel cell developed by Rolls Royce and the catalyst supplied by Johnson Matthey. Using natural gas as a hydrogen source, the intent will be to generate electricity and hot water for domestic use. An added dimension of this project is work carried out at the University of California at Riverside to route the carbon dioxide emitted by fuel cells through a greenhouse where it will be partially absorbed by plants. Thus, this demonstration will provide information on the prospects of commercializing fuel cells for homes and commercial greenhouses.

Mobile source applications

As mentioned earlier [11], methanol is an excellent carrier of hydrogen which is needed for fuel cell operation and as such, methanol is seen as a useful fuel to provide a transition to the electric vehicle.

With the introduction of the regulation requiring zero-emission vehicles in California, increased attention has focused on the means to generate electricity for electric vehicles. As indicated earlier DeLuchi and co-workers [8], carried out a study to evaluate the potential role of fuel cells in vehicles as a replacement for the internal combustion engine. Their analysis supports our belief that the fuel cell can play a constructive

TABLE 7

Japan fuel cell PC 25

Emissions	PPMV (ppm)
CO	10
NO_x	4
THC	19
NMHC	<1
SO_x	<1
Particulates	0
Smoke	0

role in the future of the automobile, and provide environmental benefits on both a global and regional scale, while also addressing the energy diversity question. Recently, a vehicle utilizing a PEM fuel cell and using metal hydride storage was unveiled by Roger Billings [14]. This appears to be the first application of a fuel cell in a light-duty vehicle.

The District has joined with the Department of Energy in supporting a demonstration of the Georgetown University hybrid fuel cell/battery bus [15]. This program is just entering its second phase to develop and test three 28-passenger buses at Georgetown University, in Chicago, and at the South Coast Air Quality Management District. These buses will be powered by a phosphoric acid fuel cell with an on-board, methanol-fueled reformer. It is anticipated that the battery, at this stage, will be lead/acid. We anticipate demonstrating this bus in the greater Los Angeles area, and to work in conjunction with the Southern California Rapid Transit District, which has an aggressive program in demonstrating alternative fuels for transit applications [16].

Increased attention has been focused on the fuel cell bus program because of the difficulty that conventional diesel but technology will have in meeting the stringent particulate and NO_x standards which are being imposed due to environmental issues. In addition, electrification of buses is being viewed very strongly in Southern California, but there is some concern about the overhead electrification lines in terms of aesthetics. Therefore, the fuel cell bus is now being evaluated more seriously for application in Los Angeles. Additionally, a program is underway in Vancouver to develop a full-size fuel cell bus using a Ballard fuel cell [17].

Additionally, the District has expressed great interest in looking at the fuel cell placement in electric vehicles [18]. We are currently discussing with the Department of Energy (DOE) the potential of participating in a fast-track program to demonstrate a solid-polymer fuel cell in a passenger vehicle. Discussions are underway with Energy Partners to initiate such a project and conduct an on-road demonstration in less than two years. We anticipate that initially this project will involve storing hydrogen on board the vehicle. However, significant work is being undertaken by DOE and others to improve the fuel reforming capabilities for on-board generation of hydrogen.

One of the key issues associated with the fuel cell is the generation and storage of hydrogen. Recognizing this, the District has embarked on several related programs. For example, the District initiated a program with Riverside Community College (RCC) to develop hydrogen as a major clean fuel of the future. This project is designed to demonstrate the health, economic and societal benefits of utilizing hydrogen as a clean-burning fuel. The project involves both engineering and converting vehicles to operate on hydrogen fuel. Hydrogen is being generated by the electrolysis of water in conjunction with the Electrolyser Corporation of Canada. The electricity required for the process will come from photovoltaic cells that use solar energy. SCAQMD and the Ontario Energy Ministry are jointly involved with this project.

The other area which needs significant work is the on-board reforming of fuels to produce hydrogen. Most work in this area has been done on methanol and we feel that the use of methanol in the internal combustion engine can be a useful precursor to the use of methanol for fuel cell vehicles. Currently the District has over 80 vehicles operating on methanol, and fueling facilities are being expanded in the Southern California area. Logically, this network would then be used for the use of methanol in reformers, either on the vehicle or at separate service stations which will produce hydrogen in addition to refueling vehicles. It is essential that demonstration and research programs continue to perfect both the storage and production of hydrogen as well as the optimization of fuel cell technology. With the increased funding for advanced battery work to satisfy the needs of the electric vehicle, we feel it is equally important that work be accelerated in the fuel cell area because of the greater long-term potential for pay offs. To this end, the District has been involved with other local and state agencies with the initiation of the Breakthrough Technologies Coalition (BTC), a lobbying organization charged with identifying a number of key advanced technologies, including fuel cells. The BTC was formed to respond to the need to identify and assure commercial demonstration of air pollution control technologies needed to attain federal ambient air quality standards. The BTC will identify potential sources of federal funding to carry out the needed research and demonstration.

Summary

The above presentation has illustrated the need for significant emissions reductions in the SCAQMD as a result of the legal requirement to meet both the federal and the California state air quality standards. In order for this to be accomplished, substantial technology improvements will be required. The fuel cell offers a particularly attractive technology to meet some of these needs. We feel that it is important that work be continued on R&D, as well as demonstration programs, to provide the type of investment needed in the fuel cell arena to bring this technology to commercialization.

In terms of the electric vehicle, we see substantial improvement in the next decade, but feel that money should not be concentrated wholly in battery development. Enormous sums of money have already been invested in battery development and we are still short of a sufficiently satisfactory market product. We feel that similar resources devoted to fuel cell development would have an equal or greater chance of success. The decades ahead promise great technology improvement strides for the electric vehicle, with concomitant improvement in air quality in the major urban areas of the world.

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