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THE CASE AGAINST ELECTRIC VEHICLE MANDATES IN CALIFORNIA

by
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EXECUTIVE SUMMARY

Air quality has been improving in Los Angeles since 1966 in spite of brisk population growth (and much faster growth of the vehicle fleet and vehicle miles traveled). Yet, air quality standards have not yet been met; new proposals to meet Clean Air Act standards include mandated electric vehicle (EV) sales in California. Proponents have suggested that the mandate also serves long-term economic growth objectives for the region.

A survey of the literature reveals substantial evidence that the EV mandate is not cost-effective; the air quality goals can be met at substantially lower cost. Resources for the Future, for example, shows that in terms of $/ton of Volatile Organic Compounds (VOC) reduced, reformulated gasoline or emissions-based vehicle registration fees are twenty times as cost-effective as EVs. In addition, there are many reasons to expect that the macroeconomic consequences of the EV mandate will be depressive rather than stimulative.

EVs will be expensive, yet short on what consumers prize most: range and power (witness the recent surge of “utility” vehicle sales). Massive subsidies and/or cost-shifts would be required that would have depressive effects on the California economy (including higher energy costs statewide). Taxpayers and/or utility ratepayers would also have to pay for new refueling infrastructure. In addition, it is not clear that EV maintenance costs will be below that of conventional autos. If consumers avoid EVs for any of these reasons, and keep their old cars longer, air quality gains will be lost.

I. AIR POLLUTION AND THE AUTOMOBILE

A. The Extent of the Air Pollution Problem

Air pollution remains a serious problem in many U.S. metropolitan areas, especially Los Angeles, where ozone levels are, on the worst days, two-and-a-half times the federal standard. The Clean Air Act of 1990 extended the timetable for attaining federal standards in nonconforming cities in Los Angeles until the year 2010. The local air pollution control agency, the South Coast Air Quality Management District (SCAQMD), is implementing a series of plans to try to achieve these goals. There is some controversy about whether the targets will be achieved, despite the fact that air quality has been improving, more or less steadily, in Los Angeles since the mid-1970s. In any event, all sources of air pollution will need to be attacked if the 2010 goals are to be achieved. It is in this context that the prospects for electric vehicles (EVs) have been touted as a means to reduce auto-related pollution.

B. The Contribution of the Automobile

Motor vehicles contribute significantly to urban air pollution, particularly via emissions of carbon monoxide and the formation of ozone. For 1991, the Environmental Protection Agency (EPA) estimated that motor vehicles accounted for 50 percent of all Carbon Monoxide (CO) emission in the United States, 29 percent of nitrogen oxides (NOx), and 27 percent of VOCs. Several air pollution investigators maintain that the 1991 EPA estimates were low by a factor of 2 or more.[1]

As vehicle emission controls have been required since 1966 in California (and 1968 in other states), emissions from new automobiles have been dramatically reduced. VOCs and CO emissions from new automobiles were cut by 60 percent in 1968 and by 96 percent in 1992. NOx emission controls began in 1972 and had been reduced by 76 percent by 1992. In absolute terms, VOC emissions are estimated by EPA to have decreased by 60 percent and CO emissions by one-half in two decades. As these differences between emissions from new cars and total emissions suggest, all vehicles on the road are not equally responsible for emissions from mobile sources. One study estimated that about 50 percent of all tailpipe emissions come from 10 percent of the fleet.[2]

Low-emission technologies for gasoline-powered internal combustion engines continue to improve. Substantial emission reductions can be achieved through the improvement of fuel atomization and combustion. Various types of catalysts including electrically heated catalysts and hydrocarbon traps will dramatically reduce cold-start emissions (a major source of automobile-related emissions), and double-walled insulating exhaust systems and close-coupled catalysts are expected to be available between the 1996 and 1998 model years.

C. Policy Alternatives

There are several ways by which mobile source emissions can be controlled or mitigated. These range from the use of low-emitting fuels and/or requiring emission control devices to reducing vehicle miles traveled (VMT) through assorted transportation control measures. Currently, replacing gasoline or diesel in motor vehicles with nonconventionally fueled vehicles is one of the methods being promoted. Alternative fuels under consideration include compressed natural gas, methanol, ethanol, electricity, and hydrogen. Fuel *replacement* requires major design changes to new cars.

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[1] Eric Fujita and Douglas Lawson, *Eval. of the Emissions Inventory on the South Coast Air Basin, final report, DRI.*

[2] This estimate suggests high potential effects of vehicle scrappage or repair programs in reducing emissions. D.R. Lawson, et al., “Emissions from In-use Motor Vehicles in Los Angeles: A Pilot Study of Remote Sensing and the Inspection and Maintenance Program,” *Journal of Air and Waste Management Association,* vol. 40, 1990.

Emissions from vehicles can also be controlled by measures that do not involve design changes to new cars. Such measures include more focused vehicle inspection and maintenance programs (the problem with the current strategy, as pointed out in a forthcoming Rand study by Jerry Aroesty and David Rubenson, is that at least 85 percent of the program's efforts are directed to testing *all* cars, most of which are clean), Stage II vapor recovery systems installed at gasoline stations to capture refueling vapors, new evaporative test procedures and standards to reduce evaporative ROG emissions, Phase 2 reformulated gasoline regulations to minimize exhaust and evaporative emissions, and vehicle scrappage programs to remove older, high-emitting vehicles from service. Compared to alternative fuel vehicle programs that depend on the slow turnover of the vehicle fleet, these measures provide immediate emission reductions at significantly lower costs.

Cost estimates (in terms of dollars per ton of VOCs reduced) for various emission control measures are shown in Table 1 (further discussed in Section VII, below). They show that reformulated gasoline, improved inspection and maintenance programs, and economic incentive measures (e.g. accelerated vehicle retirement, higher gasoline taxes and emissions-based vehicle registration fees) are far less costly than any of the low emission vehicles (TLEVS, LEVS and ULEVS) or alternative-fuel vehicles. Electric vehicles are the most expensive of all.

Table 1

Cost-Effectiveness of Alternatives to Reducing Motor Vehicle Emissions
(Estimates in $ Per Ton of VOCs Reduced)

Alternative Approaches	$ Per Ton
Command-and-Control Approaches	
Reformulated Gasoline	
Federal:	$1,900–$3,900[a]
California:	$1,400–$5,100[a]
Inspection and Maintenance	
EPA Enhanced:	$4,500–$6,000
Remote Sensing:	$2,600–$6,000
Hybrid:	$4,000–$6,000
Alternative-Fuel Vehicles	
Methanol:	$30,000–$60,000
Compressed Natural Gas:	$12,000–$22,000
Electric:	$29,000–$108,000
California Vehicles	
Transitional Low-Emission Vehicles:	$3,700–$21,000[b]
Low-Emission Vehicles:	$2,200–$27,000[b]
Ultra-Low Emission Vehicles:	$4,200–$41,000[b]
Economic-Incentive Approaches	
Accelerated Vehicle-Retirement:	$4,000–$6,000
Gasoline-Tax Increase:	$4,500
Emissions-Based Vehicle Registration Fees:	$1,650[c]

Note: Unless otherwise indicated, estimates are RFF estimates based on RFF studies or other studies. For more details on all estimates, see discussion paper 94-26, “Shifting Gears: New Directions for Cars and Clean Air” by Winston Harrington, Margaret A. Walls, and Virginia D. McConnell.

a. These EPA estimates are based on reformulation of gasoline according to EPA's recipe (which increases the price per gallon by 3 cents) and according to California's recipe (which increases the price by 8-11 cents per gallon).

b. These estimates are derived from studies by the California Air Resources Board and the Automotive Consulting Group.

c. These estimates are based on a draft study by Energy and Environmental Analysis, Inc.

Source: Winston Harrington, and Margaret A. Walls, “Shifting Gears: New Directions for Cars and Clean Air,” *Resources*, vol. 115, (Spring 1994).

II. THE STATE OF CALIFORNIA AND ALTERNATIVE FUEL MANDATES

California has been more aggressive than other states in adopting regulations and mandates to reduce ozone-forming emissions from mobile sources. CARB (the California Air Resources Board) has mandated that motor vehicle manufacturers be required to meet vehicle emission standards, in part, by producing zero emission vehicles. More specifically, CARB identified four new categories of vehicle: TLEVs (Transitional Low Emission Vehicles), LEVs (Low Emission Vehicles) ULEVs (Ultra Low Emission Vehicles) and ZEVs (Zero Emission Vehicles). The distinction is based on hydrocarbon tailpipe emissions of 0.125, 0.075, 0.04 and 0.0 grams per mile respectively. Manufacturers can choose any mix of vehicles that meet a declining fleet average emission standard. The most controversial part of the new rules is the mandate on large manufacturers (i.e., sellers of more than 35,000 vehicles per year in California) to sell 2 percent of vehicles that are ZEVs by 1998, 5 percent by 2001 and 10 percent by 2003. The state's regulated utilities are actively promoting the purchase of AFVs (Alternative Fuel Vehicles), including those powered by compressed natural gas and electricity.

A. Zev (Zero Emission Vehicle) Mandates

There are a number of arguments advanced in favor of mandates for low-emission vehicles. Air quality improvements are at the top of the list, though the State of California and many other public agencies and private groups (ranging from utilities to aerospace contractors), suggest that local ZEV mandates will translate into local jobs in manufacturing. Some analysts are concerned that Japan, Europe or Detroit will take the lead in developing this technology first, thereby reaping the benefits of many high-technology manufacturing jobs.[3]

Underlying this line of argument are assumptions that mandates are required to force ZEV technology into the commercial marketplace and that auto makers are withholding or avoiding the technology because the current market is too small. In this light, the mandates are seen as a “demand stimulus” required to jump-start the market.[4] With enough demand, manufacturers will be able to produce enough vehicles to lower their cost.

To date, the emissions regulations from the CARB for LEVs (Low Emission Vehicles) are only suggested targets. They are expected to be met via a combination of improved tailpipe emissions controls and alternative fuels, e.g. methanol.[5]

The California mandate for ZEVs takes effect in 1998 (subject to a review of the likelihood of attainment in 1996). In 1998 auto manufacturers must sell ZEVs equal to 2 percent of all new vehicles (a penalty of $5,000 per vehicle will be assessed against any shortfall), with the proportion rising to 5 percent in 2001 and 10 percent in 2003. Currently, only electric vehicles meet the requirements to be certified as zero-emissions vehicles. This means that approximately 40,000 EVs must be sold each year during the first phase, and at least 200,000 EVs by 2003, and even more thereafter. New York and Massachusetts have reached an agreement with EPA to meet the federal standards or to adopt the entire package of California standards. The latter means that nationwide EV requirements would be approximately double the

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[3] Allen J. Scott and David Bergman, Getting the Southland Back on Track, *Los Angeles Times,* November 11, 1993.

[4] Benjamin Ritchey, “Alternative Fuel Vehicle Penetration in Southern California,” memo to Jim Gosnell at SCAG dated January 14, based on Battelle report to Project California titled *Project California: Advanced Transportation Sector Analysis* dated December 1992, 1994a.

[5] *Ibid.*

California numbers. These figures compare to an annual demand in California of 2 million cars, vans, and light trucks, and in the country as a whole of more than 14 million vehicles.

B. Public Utility Commission Infrastructure Proposals

A California Public Utility Commission's (PUC's) ratepayer-funded program accounts for more than one-third ($1.2 billion) of the total cost of diverse alternative fuel vehicle (AFV) programs in California ($3 billion), excluding the ZEV mandates. The collective sales of AFVs from all the AFV programs are projected to be 220,000 between 1993 and 2010, 95 percent of which are to result from the PUC ratebase-funded programs.

The PUC regulates four private electric and natural gas utilities in California: Pacific Gas and Electric Co. (PG&E); Southern California Gas Co. (SoCalGas); Southern California Edison (SCE); and San Diego Gas & Electric (SDG&E). The California legislature has recently asked the commission to allow the utilities to undertake programs to encourage and support EVs, primarily, by providing the infrastructure necessary to recharge EVs. Specifically, the Conroy bill (AB 3239, Chapter 1000) restricts the utilities to providing only those *infrastructure* incentives that foster, "safer, more reliable, or less costly gas or electric service." Each of the four utilities now has its own individual programs of monetary cash incentives and support payments for constructing refueling stations.

The utilities have proposed six-year programs to encourage EV purchase as well as plans to provide infrastructure for EVs. They have applied for a total of $ 330[6] million in ratepayer funding. The commission's Division of Ratepayer Advocates (DRA) recommended actions that take place both at the time of purchase and afterwards, including evaluation and testing of vehicles, batteries, rechargers, infrastructure installation, customer service and public education, utility fleet programs, and system impact assessment. DRA also recommends future and ongoing EV actions by utilities for a transition towards the end of the six-year programs.

In its 1993 progress report to the California legislature, the PUC reported $51 million of ratebase funding in 1992 on R&D and demonstration of electric and natural gas-powered vehicles and associated infrastructure by the four utilities. However, over 80 percent of the $51 million was directed toward promoting natural gas vehicles (NGVs). Key PUC commissioners are said to support moving toward more ratebase funding. Funding for all LEVs for 1993 was estimated at $68 million and is expected to increase in the future.

C. Other Alternative Fuel Mandates

The California ARB adopted stricter fleet average emission standards for new vehicles sold in California, including a separate standard for sales of ZEVs (see Table 2). Beginning in model year 1994, automobile manufacturers can meet the fleet average standard only if they produce certain types of LEVs. LEVs are categorized as: transitional low-emission vehicles (TLEVs); low emission vehicles (LEVs); ultra low-emission vehicles (ULEVs); and zero-emission vehicles (ZEVs). Manufacturers may meet the fleet average standards by producing vehicles in any combination of TLEV, LEV, ULEV, ZEV or conventional vehicles, as long as their sales-weighted emissions do not exceed the fleet average standards. NGVs (Natural Gas Vehicles), for example, are one of several vehicle types that could meet the requirements of the standards, provided certain rather stringent conditions were satisfied.

In addition to fleet average emission standards affecting new vehicles sold in the state, ARB is requiring that refineries reformulate gasoline into a less-emitting product. In California, every vehicle that operates on gasoline will be utilizing reformulated gasoline by 1996.

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[6] The amount differs from the sum of $600 million cited by Michael Parrish, *Los Angeles Times* (May 21, 1994). The source of the sum mentioned in the text is the California Public Utilities Commission, Division of Ratepayer Advocates "Report on Low Emission Vehicle Program Application of SDG&E, SoCalGas, SCE, PG&E." (April, 1994).

At the federal level, the National Energy Act and the Clean Air Act Amendments of 1990 require government vehicles and centrally refueled fleets of 10 or more vehicles to switch to alternative fuels. Affected government vehicles and fleet vehicles must begin the conversion in 1993 and 1996 respectively. By these mandates, nearly 90,000 vehicles will be required to utilize alternative fuels in California by 1999.

The federal standards do not specify the type of alternative fuel to be utilized but exclude reformulated gasoline from the definition of alternative fuels. Fuels that qualify as alternatives are compressed natural gas (CNG), liquefied natural gas (LNG), liquefied petroleum gas (LPG), methanol, and electricity.

Table 2

ARB Implementation Assumptions & LEV Standards for Light-Duty Vehicles HC/NMOG Standard (grams/mile)*

Model Year	0.39	0.25	0.125	TLEVs 0.075	LEVs 0.040	0.00 Standard	ZEVs Average
1994	10%	80%	10%				0.250
1995		85%	15%				0.231
1996		50%	20%				0.225
1997		73%		25%	2%	2%	0.202
1998		48%		48%	2%	2%	0.157
1999		23%		73%	2%	2%	0.113
2000				96%	2%	5%	0.073
2001				90%	5%	5%	0.070
2002				85%	10%	5%	0.068
2003				75%	15%	10%	0.062

* The hydrocarbon emission limits are expressed in terms of reactivity-adjusted nonmethane organic gases (NMOG).

III. DEMAND FOR ALTERNATIVE VEHICLES AND FUELS

Three types of studies have examined the questions of consumer choice and, therefore, market potential for various types of vehicles. Econometric studies examine actual purchases and vehicle characteristics to assess the value to consumers of vehicle attributes. Surveys and economic tradeoff analyses examine the potential tradeoff between purchase and operating costs on the one hand and an expected opportunity cost on the other hand. Market niche studies concentrate on the ability of a proposed class of vehicles to satisfy actual or projected travel behavior regardless of vehicle characteristics.

In general, econometric studies have estimated the smallest potential markets for EVs, economic tradeoff analyses have suggested that the markets are somewhat larger, and market niche studies have estimated the largest potential markets. The strength of econometric analyses is that they rely on revealed preferences through actual market behavior. The economic tradeoff analyses rely on survey responses to hypothetical choices and are believed to be less reliable and less accurate. Market niche studies have no relationship to market behavior. They estimate the numbers of conventional vehicles that could be replaced by EVs, based strictly on technical requirements and actual travel behavior. Consumer preferences are not considered in making estimates of the numbers of vehicles that could be sold.

A. Econometric Studies of Vehicle Attributes

Econometric studies such as those pioneered by Charles Lave and Kenneth Train[7] [8] use hedonic techniques[9] to measure the value of such attributes as vehicle performance, range, and size. Both monetary and nonmonetary attributes of vehicles and fuels affect the likely demand for future transportation technology. The nonmonetary attributes include the availability of fuel and convenience of refueling or recharging, range between refueling or recharging, vehicle performance, and vehicle comfort.[10]

For example, Arguea, Hsiao and Taylor[11] have conducted a hedonic demand study to identify and rank consumer preferences for automobile *characteristics***.** Their data are from *Consumer Reports* and *Ward's Automotive Yearbook*. They study buyers' actual behavior rather than stated intentions in order to avoid the biases inherent in survey responses. The findings indicate a strong preference for high-performance vehicles (these authors show that horsepower is in great demand); the income elasticity of demand for horsepower is greater than one (1.261); as incomes rise, the demand for this attribute rises more than proportionately. In contrast, the income elasticity of demand for fuel economy (MPG) is less than one. The authors also report that size (comfort) and performance are complements.

The inferred preference for size and performance is consistent with real-world shifts in demand in favor of sports utility vehicles (SUVs) and minivans. The combined share of these two markets increased from 8.9 percent in 1986 to 17.7 percent in 1993 (Table 3), and is continuing to grow (especially now that the key safety features are being incorporated into new models of these types). These vehicles, because of their weight and power requirements, are the *least* suitable for electric power.

Table 3

Market Share of Sport Utility Vehicles (SUVs) and Minivans, 1986–93

Sales (000s)	1986	1987	1988	1989	1990	1991	1992	1993
Total Vehicles	16,322	15,189	15,679	14,713	14,143	12,539	13,117	14,199
SUVs	823	905	961	945	929	910	1,133	1,380
Share (%)	5.0	6.0	6.1	6.4	6.6	7.3	8.6	9.7
Minivans	637	718	841	844	926	878	977	1,140
Share (%)	3.9	4.7	5.4	5.7	6.5	7.0	7.5	8.0
SUV & MV (%)	8.9	10.7	11.5	12.1	13.1	14.3	16.1	17.7

Sources: *American Automobile Manufacturers Association* and *Ward's Automotive Reports*

Considering the probable high price of an EV (in the absence of massive cross-subsidization), moderate-to-high income earners are the most likely market for new electric vehicles. Yet electric vehicles have weaker performance and/or less space than the conventional vehicles these consumers demand. These findings suggest problems with the marketability of electric vehicles.

B. Surveys and Economic Trade-off Analyses of Vehicle Attributes

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[7] Charles Lave and Kenneth Train, “A Disaggregate Model of Auto-Type Choice,” *Transportation Research*, vol. 13A, (1979) pp. 1-9.

[8] Kenneth Train, *Qualitative Choice Analysis: Theory, Econometrics, and an Application to Automobile Demand* (Cambridge: MIT Press, 1986).

[9] Hedonic Techniques estimate the implicit prices which consumers will pay for characteristics which distinguish one item in a class from another item for the same class.

[10] *Ibid.*

[11] N.M. Arguea, C. Hsiao, G.A. Taylor, “Estimating Consumer Preferences Using Mraket Data—An Application to U.S. Automobile Demand,” *Journal of Applied Econometrics*, vol. 9, 1994, pp. 1–18.

Economic tradeoff analyses have been used to assess the value of vehicle attributes using surveys based on the concept of avoidance costs. In one case, a distribution of travel behavior is derived, and all trips which exceed the capabilities of an EV are assumed to require the use of a rental vehicle. Market potential is then estimated based on the difference between higher purchase costs of an EV versus lower operating costs (including probable rental costs). In other cases, respondents are given hypothetical choices of vehicles with varying capabilities and asked which vehicle they would prefer.

In a discrete choice, stated preference survey of this second type, David Bunch *et al.*[12] found that nonmonetary attributes are more important determinants of consumer choice than monetary purchase and operating costs. The study analyzed survey responses on the specific attributes that influenced preferences. The seven attributes found to be the most important to consumers were: a) range between refueling/recharging; b) availability of fuel/recharging stations; c) vehicle purchase price; d) operating cost; e) vehicle performance; f) dedicated vs. multi-fuel capability; and g) the level of emissions reductions compared to current vehicles.[13]

The single most important attribute is vehicle range, as confirmed in a number of studies.[14] [15] [16] [17] [18] Although studies have confirmed that most average daily use would be accommodated within a range of 100 miles, survey respondents consistently demand greater range (150 to 200 miles at a minimum).

Of the important attributes listed above, only the potential for emissions reductions clearly favors electric and alternative fuel vehicles. The operating cost situation is unclear because, although electricity for recharging is cheaper than gasoline, the periodic replacement of battery packs is currently very expensive. One estimate puts the price of lead-acid battery replacement at $3150.00, and projects that replacement will be required every three years over the vehicle's 10-year life cycle. Nickel-Cadmium batteries last longer, but have a higher initial cost[19]

Bunch et.al.[20] found the potential for emissions reductions to be an attribute of vehicles that could positively affect future market choices for EVs. The effect was small but consistently significant, leading the authors of the survey to conclude that there is a “green” segment of the vehicle market that would purchase vehicles in part for their emissions characteristics. However, other studies offer little evidence that can be used to corroborate their results. Also, because emissions reductions are a public good, individuals may realize the benefit without purchasing a vehicle, while their purchase would confer uncompensated benefits on others.

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[12] David S. Bunch, Mark Bradley, Thomas F. Golob, Ryuichi Kitamura, and Gareth P. Occhiuzzo, “Demand for Clean-Fuel Vehicles in California: A Discrete-Choice States Preference Pilot Project,” *Transportation Research A,* vol. 27A(3), (1993) pp. 237-253.

[13] These attributes are not listed in any particular order.

[14] *Ibid.*

[15] John E. Calfee, “Estimating the Demand for Electric Automobiles Using Fully Disaggregated Probabilistic Choice Analysis,” *Transportation Research B,* vol. 19B(4), 1985, pp. 287-301.

[16] Steven D. Beggs and N. Scott Cardell, “Choice of Smallest Car by Multi-Vehicle Households and the Demand for Electric Vehicles,” *Transportation Research A,* vol. 14A, 1980, pp. 389-404.

[17] S. Beggs, S. Cardell, and J. Hausman, “Assessing the Potential Demand for Electric Cars,” *Journal of Econometrics,* vol. 17, 1981, pp. 1-19.

[18] David L. Greene, “Estimating Daily Vehicle Usage Distributions and the Implications for Limited-Range Vehicles,” *Transportation Research B*, vol. 19B(4), 1985, pp. 347-358.

[19] W.R. Moomaw, et al., *Near-Term Electric Vehicle Costs,* Medford, Mass.: Tufts University, prepared for the Northeast Alternative Consortium.

[20] Bunch, et al., “Demand for Clean-Fuel Vehicles in California,” pp. 237-253.

The results of consumer studies of vehicle choice indicate that socioeconomic variables also play an important role in vehicle choice. Bunch *et al.*[21] found that college education had a positive effect on stated preferences for electric cars and that longer commute distances (subject to the range constraint) led respondents to choose vehicles with the lowest fuel costs (potentially electric cars). However, respondents aged over 55, in larger households, and with higher incomes stated a significantly lower preference for electric cars.

There is also a relationship between the class of vehicle intended for purchase and a buyer's preference for low-emissions vehicles. People intending to buy a sport utility vehicle (currently the hottest market segment) have a lower preference for electric cars than people intending to buy smaller four-door sedans. This may be due to considerations of range, performance, and recharging availability, or it may be because of an image problem affecting electric cars, or both. It is apparent from the current popularity of four-wheel-drive sport utility vehicles (Table 3) and larger luxury sedans that the market is moving in the opposite direction from the type of subcompact car likely to dominate the alternative fuel vehicle (especially EV) market.

C. Market Niche Studies

Market niche studies concentrate on the capabilities of EVs in terms of actual travel capability. The calculation is based on a derived distribution of travel demand compared to an assumed range and recharging schedule for electric vehicles.[22] These studies estimate larger market shares for EVs than econometric and survey analyses.

The potential market for EVs and AFVs is identified by Timothy Henderson and Michael Rusin[23] as well as by Benjamin Ritchey[24] [25] as initially consisting of a commercial fleet submarket and a household second-car submarket. Commercial fleets of local delivery vehicles are currently being used to test EVs in demonstration projects. As with passenger transportation, the limited range of EVs limits their potential success. A 1987 study by the Electric Vehicle Development Corporation[26] found that delivery vans with a range of 75 miles could technically replace 160,000 delivery vans in the 30 largest urban areas. A survey by Daniel Hill[27] suggests that commercial users are the most willing to cope with the limitations of such vehicles.

The household second-car market is potentially much larger. But John Calfee[28] predicts that the likely market success of electric vehicles with “modest” performance is insignificant. Even in households that already owned at least one conventional automobile, the market for an electric car with lower operating costs but limited range (under 100 miles) and slower acceleration (although the GM Impact claims a 0-60 m.p.h. of 8.0 seconds) was found to be negligible. The study showed that a range of 150 miles or more

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[21] *Ibid.*

[22] e.g. David L. Greene, “Estimating Daily Vehicle Usage Distributions and the Implications for Limited-Range Vehicles,” *Transportation Research B*, vol. 19B(4), 1985, pp. 347-358.

[23] Timothy P. Henderson and Michael Rusin, “Electric Vehicles: Their Technical and Economic Status,” Washington: American Petroleum Institute, Research Study No. 073, 1994.

[24] Ritchey, “Alternative Fuel Vehicle Penetration.”

[25] Benjamin Ritchey, “Electric Vehicle Penetration in Southern California,” memo to Jim Gosnell at SCAG dated January 14, based on Batelle report to Project California titled *Project California: Advanced Transportation Sector Analysis*, dated December 1992, 1994.

[26] Henderson, et al, “Electric Vehicles.”

[27] Daniel H. Hill, “Derived Demand Estimation With Survey Experiments: Commercial Electric Vehicles,” *Review of Economics and Statistics*, vol. 69(2), 1987, pp. 277-285.

[28] Calfee, “Estimating the Demand for Electric Automobiles,” pp. 287-301.

and acceleration similar to gasoline-powered vehicles would be necessary to attract significant market interest. However, Mark DeLuchi *et al.*[29] believe that the technical limitations will soon be overcome to a degree that makes these vehicles viable as second cars.

But reliance on a single variable such as range to determine market potential is not warranted. Consumers base their decisions on many vehicle attributes, although vehicle range remains the single most important attribute.[30] [31] [32] Adequate range for the majority of trips is not enough to sway the choice to electric vehicles, even as a second car. In Southern California, for example, although the average daily work commute is less than 40 miles round-trip, occasional total daily use of greater than 100 miles is not uncommon. Moreover, the growth of two-worker households means that many spouses need a second car for commuting, not merely for local trips. Drivers place great value on being able to accommodate their expected *maximum* use, rather than on a high probability of meeting their *average* use.

Kevin Nesbitt *et al.*[33] found that infrastructure constraints and travel requirements further limit the potential household submarket for EVs. To identify potential buyers, their study used the following criteria: a) home ownership with a garage or carport (necessary to invest in charging facilities); b) household car ownership of 2 or more vehicles; and c) at least one household member with a commute of less than 80 miles round trip per day. The authors found that 28 percent of households nationwide met these criteria. Relaxing these constraints increased the number of households to 38 percent. Also, household second cars are typically less expensive than primary cars, with drivers either using older vehicles or buying used vehicles, so that a cost premium for EVs could be a major constraint.

Ren *et al.*[34] combine the econometric and market niche approaches by estimating hypothetical vehicle choices, given the household's current vehicle holdings and specified attributes of EVs compared with other AFVs (CNG and methanol). Their results show a range of 2.6–4.4 percent of all automobile purchases for electric vehicles, well above the 1998 target. However, some of their stated EV attributes (in particular, a purchase price of $21,000 and the failure to include the high cost of battery replacement in estimating fuel costs) may be too favorable to the EV case.

D. Factors Affecting the Likely Success of Electric Vehicles

Even with a level of performance similar to existing gasoline-powered cars, the success of EVs would also depend on their purchase price and operating costs. The premium for prototype electric vehicles is currently high. In 1993, the cost difference between gasoline-powered vehicles and electric conversions of the same vehicles (Ford Escorts, Chevrolet S-10 pickups, Pontiac Fieros) was about $10,000 or roughly double the original price of the vehicles, according to Henderson and Rusin.[35] This difference could be reduced if battery technology improves substantially prior to the effective date of the mandates (1998). Less expensive cars are being developed, but to date they have been of extremely limited range, with poor performance and limited features.

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[29] Mark DeLuchi, Quanlu Wang, and Daniel Sperling, “Electric Vehicles: Performance, Life-Cycle Costs, Emissions, and Recharging Requirements,” *Transportation Research A* vol. 23A(3), 1989, pp. 255-278.

[30] Bunch, et al., “Demand for Clean-Fuel Vehicles in California,” pp. 237-253.

[31] Calfee, “Estimating the Demand for Electric Automobiles,” pp. 287-301.

[32] David L. Greene, “Estimating Daily Vehicle Usage Distributions and the Implications for Limited-Range Vehicles,” *Transportation Research B*, vol. 19B(4), 1985, pp. 347-358.

[33] Kevin A. Nesbitt, et al., “Home Recharging and the Household Electric Vehicle Market: A Near-Term Constraints Analysis,” Institute of Transportation Studies, University of California, Davis, January 1992.

[34] W. Ren, D. Brownstone, D.S. Bunch and T.F. Golob, “A vehicle transactions choice model for use in forecasting demand for alternative-fuel vehicles,” *Research in Transportation Economics*, 1994, forthcoming.

[35] Henderson, et al., “Electric Vehicles.”

The price premium for mass-produced alternative fuel vehicles and future electric vehicles is unknown. California ARB staff estimate the price premium for ultra-low-emission alternative fuel vehicles to be as low as $214. In contrast, vehicle manufacturers estimate the premium to be as high as $2,799. The price range for electric vehicles is even greater. ARB estimates the premium to be $1,436. Manufacturers say it could be as high as $56,000 (the Chrysler minivan premium is estimated to be about $25,000). The price of the GM Impact EV, a two-seat economy sports car, might be at least $25,000;[36] *Motor Trend* (August, 1994)[37] estimated the price of a Ford Escort EV utility van to be about $100,000). The electric version of the Peugot 106 has a projected premium of $3,000–$4,000, and this is an economy model.

Life cycle costs of EVs are expected to be higher than for conventional vehicles. In addition to a higher initial purchase price, the costs of periodically replacing the batteries and investing in a charging station raise total costs beyond that of conventional cars even after considering potentially lower maintenance and energy costs.[38]

The current generation of EVs will likely cost more and perform less well than conventional automobiles. Supporters of electric vehicles thus propose various incentives and subsidies to increase the attractiveness of EVs in the market. Proposals include preferential parking, reduced electric rates, tax credits federal and State of California credits already exist) and subsidies for both buyers and manufacturers, exemptions of sales taxes and registration fees, authorization of HOV lane use for single drivers, and pollution taxes for conventional cars.[39]

Market penetration of EVs is projected by Ritchey,[40] using a market niche type of analysis, to range from 1.7 percent to 5 percent in 1998 (these are consistent with the Ren *et al.*[41] numbers referred to above), rising to a range of 13.7 percent to 30 percent in 2010. Initially, these proportions depend on adoption of EVs in government and delivery fleets. By the year 2010, market share will depend on advanced technology in batteries that will extend vehicle range, on complete charging infrastructure being in place, and on an aggressive program of education and incentives.

The market success of other alternative fuel vehicles is likely to be greater than for EVs,[42] [43] estimated CNG shares and methanol shares in the 14 percent to 22-percent range for the year 1998. The reasons include greater power and range, lower cost premiums, and more convenient refueling. In some cases AFVs are outwardly indistinguishable from conventional gasoline vehicles, because they require only moderate engine conversion (as in methanol vehicles). Ritchey[44] estimates that market penetration for AFVs would range from 14 percent to 34 percent of the market by the year 2010. The share is dependent on refueling opportunities as well as upon buyer perceptions.

It is probably optimistic to expect a battery to be developed in time to meet the performance and cost attributes required for a 1998 model-year mass-produced and marketable electric vehicle. The automakers are already lagging behind the timeline of their typical product development cycles in the

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[36] *Los Angeles Times,* October 11, 1994.

[37] *MotorTrend.*

[38] Henderson, et al., “Electric Vehicles,” p. 31.

[39] *Ibid,* p. 25.

[40] Ritchey, “Electric Vehicle Penetration.”

[41] Ren, et al., “A Vehicle Transactions Choice Model.”

[42] Ritchey, “Alternative Fuel Vehicle Penetration”; and Ritchey, “Electric Vehicle Penetration.”

[43] Ren, et al., “A Vehicle Transactions Choice Model for Use.”

[44] Ritchey, “Alternative Fuel Vehicle Penetration.”

case of EVs. Radical changes in scheduling may be necessary because the component technologies have not yet been proven. Rushed and concurrent development of this kind does not allow time to test each component and increases risks of failure.

Because the powertrain is the essential core of any type of vehicle design, the lack of an advanced battery has forced the automakers to compromise in the first generation EV designs for 1998. Batteries now available for use in 1998 model year vehicles are lead-acid and nickel cadmium batteries. While nickel cadmium batteries provide quicker acceleration and longer range, they are more expensive than lead-acid batteries which are much heavier and bulkier. General Motors intends to produce a nickel-metal hydride battery. There are technical problems in its development and projected costs are very high, but there are offsetting benefits in terms of battery life, increased range (perhaps 110 miles), and faster recharging times.

On behalf of Western States Petroleum Association (WSPA), Dennis Virag estimated the retail prices for mass-produced EVs available in 1998 in the $28,000–$48,000 range. Virag also predicted that 70 percent of all components in an EV must be changed from conventional technology to improve performance and make EVs acceptable to customers. For example, replacement of the steel auto body with aluminum (to save weight) could add $2,000 to a new vehicle.[45]

Development cost per vehicle is dependent on the number of vehicles produced. Given the limited sales potential and high development costs, the price premium estimated by ARB ($1,436 per vehicle) is not realistic.

Some EV advocates argue that maintenance of EVs will be less expensive and simpler than that of conventional vehicles. These advantages could offset the higher purchase price of EVs. However, internal combustion engine technologies have evolved, demonstrating observable improvements over the last ten years and will continue to advance, substantially reducing maintenance costs. Automobile manufacturers are continuing to extend the time between service intervals. For example, the new Ford Contour/Mystique will require no scheduled engine service other than oil changes for 100,000 miles. While current electrical and electronic systems are less prone to failure than mechanical systems, it is more difficult and expensive to diagnose and repair these systems because of their high degree of integration.

Performance attributes of EVs such as limited ranges, limited utility in terms of passenger or cargo space, heavier weight, and, in most cases, poorer acceleration than comparable internal combustion engines are also barriers to consumer acceptance of EVs, at least at the early stages of the product life cycle. Because of the battery weight of 1,000 to 1,500 pounds, it is necessary to use sturdy designs for vehicle body, suspension, brakes, wheels, and tires given current battery technology. This will add significant vehicle weight and limit driving range unless nontraditional technology and materials are developed. Driving range can be increased by increasing the number of batteries on board, but passenger and/or cargo space will then have to be reduced further.

There also exists a trade-off between peak power output and energy storage. Even the batteries under development to meet the “mid-term” goal set by the U.S. Advanced Battery Consortium will be forced to make this trade-off. In other words, increased energy storage aimed at enhanced range results in poorer acceleration. In addition, the operation of other on-board systems such as air conditioning or heating can reduce the expected range by 20 percent.

Consumers trade off performance with price. Without significant subsidies or major technological breakthroughs, electric vehicles will cost more and perform less well than conventional vehicles. For a more optimistic view of the comparative costs of EVs (arguing that the costs of purchase, operation and maintenance are only 6 percent higher than those of conventional vehicles, see Moomaw *et al*.)[46]

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[45] Bevilacqua-Knight, Inc. Report Number, BKI-92-100 (April 1992), “1992 Electric Vehicle Technology and Emission Update,” cited from prepared testimony of James M. Lyons on behalf of WSPA (May 2, 1994).

[46] Moomaw, et al., *Near-Term Electric Vehicle Costs.*

IV. THE SUPPLY OF ALTERNATIVE VEHICLES

A. The Automobile Industry and the State

Some California policymakers envision an advanced transportation industry established within its borders (e.g., Calstart). Another view, presented by WSPA, holds that it is unrealistic to expect any automaker to open a production facility in California. Because automakers attempt to utilize available facilities, it is more likely that they would reopen a closed plant or expand at a current site (and the options in California are few, e.g., GM's now-closed Van Nuys plant). Although California has been responding to criticisms of the state's less than ideal “business climate” by providing tax concessions, various types of exemptions, and public subsidies, the consensus of academic researchers is that these fiscal advantages do not affect location decisions significantly.[47]

Automotive suppliers are very sensitive to production costs. A number of suppliers have relocated their plants to lower cost areas such as Indiana, Arkansas, Tennessee, and Kentucky in the last 15 to 20 years. Also, component suppliers and vehicle assembly plants are increasingly co-located, especially as a result of the adoption of just-in-time inventory systems.

B. Cost-Shifting Implications

The existing California and proposed Massachusetts and New York mandates require that auto makers sell large numbers of low emission and zero-emission vehicles on a specific timetable. The manufacturers claim that they will be unable to meet the targets for a number of reasons, including the probable high cost of electric and alternative-fuel vehicles.

Cost is likely to be a significant barrier to market success. Manufacturers will be forced to engage in cost-shifting in order to sell enough vehicles to meet the targets (and to avoid the $5,000-per-vehicle penalties), setting the price of low-emission vehicles below cost and recovering their losses by raising the prices on conventional gasoline vehicles. They may even be called on to justify such actions by claiming that the higher prices are a sort of “toll” or externality tax necessary to get low-emission vehicles onto the roads so they can begin to clean up the air. DRI/McGraw-Hill[48] estimated that the price of every new gasoline-powered vehicle sold in California could increase by $400 to $4400 by the year 2010 just to cover the cost of mandated sales of electric vehicles. The chairman of Chrysler stated that EVs would have to be sold for about $2,000 less than gasoline cars to attract buyers, with the revenue gap filled by a surcharge on all other Chrysler vehicles sold in California. Taking the Voyager/Caravan as an example, the cost for an EV (including batteries) might be $45,000 rather than an average price of $20,000; the subsidy per conventional vehicle to meet the 1998 goals would have to be $500.

The electric utility industry is a prominent supporter of electric vehicles and electric-powered mass transit systems. Most electric utilities are regulated essentially on a cost-plus basis. In addition, they are often subject to favorable tax treatment of investments in capacity, making higher demand for electricity doubly welcome. The suggestion that electric vehicles will mostly be charged at night means that off-peak demand would increase, allowing increased revenues at the lowest marginal cost. The utilities themselves are involved with the development of vehicles and the infrastructure that will become necessary for running them, including upgrading the power grid, building retail charging stations, and improving residential and commercial connections.

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[47] Michael Wasylenko, “Empirical Evidence on Interregional Business Location Decisions and the Role of Fiscal Incentives in Economic Development,” *Industry Location and Public Policy,* Knoxville: University of Tennessee Press, 1991.

[48] DRI/McGraw-Hill, *Economic Consequences of Adopting California Programs for Alternative Fuels and Vehicles*, Washington: DRI/McGraw-Hill and Charles River Associates, 1994.

The Electric Power Research Institute welcomes an expanding role for electric utilities, and hence "the utility industry is able to champion electric transportation as never before." Its mission is "to initiate, develop, and seek partners for projects and programs designed to help the industry achieve its long-term goals."[49] EPRI has publicized a five-year plan for vehicle and infrastructure development. The components include connecting and charging technology, building-code revisions ("to ensure that buildings and communities are EV-ready,"[50] load management and distribution, battery development, and new vehicle prototypes. To take one example, the electric utility industry has invested $75 million in battery technology over the past 15 years.[51] It participates in the United States Advanced Battery Consortium (USABC) along with the major auto manufacturers and the Department of Energy. As a result of their enthusiasm for these new vehicle mandates, utilities will increase their costs willingly and shift costs, through regulated rates and cross subsidies, to all consumers of electricity.

In this context, it should be noted that electricity rates in California are already 50 percent higher than the national average and double those in many other western states.[52] There is a precedent for EPRI's suggestions. Utilities already subsidize the purchase of energy-efficient equipment by industries and even homeowners (for example, fluorescent lighting, additional insulation, refrigerator rebates). The subsidies are paid for by raising rates across-the-board, in effect taxing all consumers to pay for energy savings by some. The PUC is currently studying utility requests to use $330 million in ratepayer funds to encourage the use of electric vehicles through construction of charging stations.[53] It is likely, however, *that $300 million* will be approved. SCE alone plans to spend $210 million on chargers for EVs, $35 million of which would be for residential garages.[54] SCE estimates the cost of individual home chargers to be about $1,000 per installation. DRI/McGraw-Hill[55] estimated that the cost of these subsidies statewide could reach $2.2 billion by 1998 via incentives, tax exemptions, and direct funding of charging stations and electric bus lines.

Cost-shifting of another type will be induced through the various public policy measures adopted in an effort to spur adoption of electric vehicles. The federal Energy Policy Act of 1992 authorizes a vehicle purchase tax credit of 10 percent of initial cost, to a maximum of $4,000; a tax deduction for alternative fuel refueling property; and $50 million for a demonstration program.[56] The City of Los Angeles, through the Department of Water and Power, has awarded grants to manufacturers of vehicles and batteries. The State of California authorized a state tax credit of $1,000, which expired at the end of 1994, and a partial sales tax exemption that would be worth $1,450 on a $30,000 vehicle.

While utilities plan to control the time of recharging so that they could minimize operating costs, this will not necessarily occur. According to the utilities' analysis, the residential and commercial vehicle recharging schedule can be managed to result in 95.5 percent of home-based recharging occurring during off-peak hours. However, an analysis conducted by California Energy Commission staff in 1992[57]

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[49] EPRI, "Electric Vehicle Infrastructure: The Key to Successful Introduction," Electric Power Research Institute, 1993, Rpt.TR-10254.

[50] *Ibid., p. 2.*

[51] *Ibid.*

[52] R.L. Bradley, Jr., *Second Quarter 1994 Report*, Houston: Institute for Energy Research, 1994.

[53] Michael Parrish, "Building Up Power: Mandate for Electric Vehicles Gives Infrastructure a Charge," *Los Angeles Times*, May 21, 1994, p. D1.

[54] Liz Mullen, "Electric Car Battery Maker Looks to Open Plants Here," *Los Angeles Business Journal*, May 23, p. 6.

[55] DRI/McGraw-Hill, *Economic Consequences of Adopting California Programs.*

[56] Henderson, et al., "Electric Vehicles," p. 25.

[57] California Energy Commission Staff Report (Feb. 10, 1992), "Analysis of the Potential Electricity Demand, Electricity Supply and Emissions Impacts of Electric Vehicles," cited from the Prepared testimony of James M. Lyons on behalf of WSPA, May 2, 1994.

indicates that the “natural” demand for recharging is very different. The CEC staff concluded that significant recharging would take place throughout the day and the recharging peak would be from 5 to 8 p.m. If this were the case, it would severely limit the use of EVs during the evening. In addition, the assumption of minimal peak-period charging is inconsistent with the proposal to install charging facilities in parking lots at commercial and employment centers. Peak-period recharging will impose a substantial amount of additional energy load, which will result in higher system operating costs than estimated. Ratepayers are expected to share these increased costs because of ratebased funding.

The high costs of EVs can be shifted but they are inescapable. Consumer-taxpayers will pay in one more of the following ways:

1) higher prices of all vehicles sold, as a result of auto industry cost-shifting;

2) higher energy rates than at present; and

3) higher taxes to fund government subsidies to EV buyers.

Each of these will have a depressing effect on the economy. In addition, it is doubtful that the EV mandate will bring a viable auto industry to California. Recent plant openings have been in settings where the costs of doing business are substantially lower than here. Moreover, considerable cost-shifting cannot be the basis for statewide industrial expansion. Quite the opposite is true: cost-shifting is likely to make California an even more expensive place for many industries.

In addition, background conditions in California are unfavorable to the diffusion of EVs. Among global automobile manufacturers, the French company, Peugot Citroen, has been one of the strongest advocates of EVs. They propose to sell about 10,000 electric vehicles a year in Europe “in the not-so-distant future.” These are electric versions of existing, small conventional models (Peugot 106 and Citroen AX), costing $3,000–$4,000 more then the gasoline-powered models (before tax and *excluding the battery*). However, the executive vice-president of the company, Jean-Yves Helmer, argued that France (as opposed to the United States in general or California in particular) offered a good EV market because: 1) more compact urban areas meant shorter driving distances; 2) 90 percent of electricity in France is nuclear or hydro so that there are few emissions offsets from electricity generation; and 3) gasoline is expensive.[58]

V. ENVIRONMENTAL IMPACTS OF TRANSPORTATION MANDATES

A. Air Pollution Reductions from Electric Vehicles

The Clean Air Act, most recently amended in 1990, is aimed at reducing air pollution in urban areas. One element mandates tough vehicle emissions standards for new cars. The amendments also require the introduction of alternative-fuel vehicles. California has taken the approach a giant step further by requiring ZEVs (*de facto*, EVs) to be sold in the state.

Henderson and Rusin present a survey of eight environmental studies that compared electric vehicles to conventional gasoline.[59] These analyses presented 15 comparisons of scenarios (7 of which were for Southern California) with varied assumptions about electricity generation, vehicle and power plant emissions controls and efficiency, fuel economy, maintenance rates, vehicle miles traveled, and resource extraction. The results favored EVs and were robust across most scenarios.

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[58] J.-Y. Helm, “EVs 12,” Memorandum distributed at Press Conference in Anaheim, California, on December 2, 1994.

[59] Henderson, et al., “Electric Vehicles,” Appendix IV.

In general, the comparisons showed that replacement of conventional automobiles with EVs would decrease emissions of most pollutants, including carbon monoxide, hydrocarbons, and volatile organic compounds. There is some uncertainty over the impact on nitrogen oxide emissions due to assumptions about fuel formulations and emission controls. Most scenarios showed that sulfur compound emissions and particulates would increase due to increased electricity generation. These results assume current emissions-control practices on the part of generators.

A recent study by EPA has stirred controversy about these conclusions. EPA estimated that air quality could deteriorate as a result of replacing conventional gasoline vehicles with EVs. But the EPA study may be seriously flawed. The main problem is that the study assumed coal-fired electric generation, based on experience in the northeastern states, whereas California electric generators use mainly natural gas and some oil in a much cleaner process.

When total emissions from EVs (power generation included) are compared to total emissions from gasoline-powered cars, EVs look good. On a per-vehicle basis the reductions in individual pollutants are substantial, ranging from 75 percent to 99 percent depending on the scenario and assumptions.[60] However, because electric vehicles are unlikely to make up a large percentage of the total number of vehicles on the road barring some major technological breakthrough, the net impact on air pollution will be small.

While California electric generators plan to produce electricity from gas-fired generators, the prospects of switching power generation from higher-emitting facilities can be exaggerated. The power plant emission analysis of the utilities on assumptions that are subject to substantial variations requires close examination before it is incorporated in the assessment of air pollution reductions from EVs. For instance, SCE's emission forecasts at power plants have been analyzed by James Lyons on behalf of WSPA. He indicated that SCE's analysis is deficient because of major inconsistencies in their assumptions about fuel price, emission control requirements, and vehicle-charging profiles.[61]

Fuel costs at the gas-fired generating units are expected to be high. These higher costs could shift generation away from equipment fired by gas if their marginal costs exceed those of other available resources, because utilities deploy their generating resources so as to minimize operating costs. It is probable that the increased electricity demand will be met by other higher-emitting resources. To the extent that this shift occurs, the incremental generating emissions due to the program would be higher than those estimated.

The forecast marginal emission rates of the EV load are dependent upon the emission controls in use at each generating unit. In predicting system emissions as a result of the EV load, SCE assumed that the requirements of SCAQMD Rule 1135 would be in effect. Its compliance plan includes the retrofitting of sixteen existing utility boilers with selective catalytic reduction (SCR) systems to control NOx emissions. However, SCE recently filed an application with the PUC in which the utility indicated that the planned installation of five SCR systems can be deferred without affecting its ability to comply with the RECLAIM (Regional Clean Air Incentives Market) emission limits. SCE's filing also indicates that it may be more cost-effective to purchase RECLAIM trading credits than to retrofit additional emission controls to comply with future RECLAIM emission rates. By not installing planned SCR retrofits, NOx emissions from in-basin generating resources, fired by gas, could be greater than estimated. Also, to the extent that generation is shifted out of basin to maintain in-basin emission averages, the use of other higher-emitting generating capacities might increase.

Even if the number of EVs in operation grows, the reduction in emissions will be limited because EVs are not capable of fully replacing the vehicle miles traveled by gasoline-powered automobiles because of their

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[60] *Ibid,* p. 77.

[61] Bevilacqua-Knight, “1992 Electric Vehicle Technology.”

limited range, using current and anticipated technologies. Sierra Research[62] estimated that an EV with a 100-mile range would be capable of offsetting 78.8 percent of the miles traveled annually by the average motorist driving a gasoline-powered vehicle. Another study performed by Bevilacqua Knight[63] for ARB, which is frequently referenced in the utilities' filings, contains an estimate of only 50 percent as the proportion of gasoline-powered vehicle travel that EVs with a 100-mile range will be capable of offsetting. The proportion of vehicle miles that will be driven by EVs is more important than the number of EVs purchased in assessing their air quality impacts, and given its limited capability of offsetting vehicle travel, actual emissions reductions from EVs may be less than hoped for.

The effects of a combination of other factors (e.g., LEV programs in general, Phase 2 gasoline regulations, changes in vehicle fleet characteristics and usage, and changes in the basic emission rates assumed for vehicles) should be addressed while estimating emission reductions attributable to EVs. Comparison of EV emission benefits with those realized from a combination of other control measures is more meaningful than comparison of total emissions from EVs to total emissions from gasoline-powered cars without considering expected advances in its technology, let alone the comparison of emission reductions on a per-vehicle basis.

The price premium associated with EVs will cause fewer new vehicles (of all kinds, depending upon the degree of cost-shifting) to be sold and older, higher-emitting vehicles to be kept longer and driven more. This would accelerate an ongoing trend (twenty-five years ago the average car was five years old; now it is eight years old) and, thereby, lower the emission reductions of ZEV mandates by offsetting the potential air quality benefits from EVs.

Additional reductions in average HC (hydrocarbon) emissions from new vehicles because of the introduction of EVs is nearly nonexistent. Only a small reduction in NOx emissions is attributable to the introduction of EVs. This negligible contribution of EVs to emission reductions is because new vehicles must meet already stringent emission control requirements and, on average, the same tailpipe emission standards for HC whether or not EVs are introduced.

The air pollution benefits attributable to the introduction of EVs appear to be more problematic when the costs associated with the EV mandates are considered. In addition to the production costs that include development costs and public funds required to support various EV programs discussed earlier, there are factors that may increase the costs much beyond standard estimates. An Environmental Defense Fund[64] study of the Northeast suggested a wide range of compliance costs between $2.059 billion (1995 prices) and $23.172 billion. These potentially high compliance costs induced the EDF to conclude that “it is time to halt the endless legal maneuvering around vehicle control requirements and get down to the job of producing emissions reductions.”[65]

B. Air Pollution Reductions from Alternative Fuel Vehicles

When emissions from AFVs are compared to emissions from gasoline-powered cars, the per-vehicle pollutant reductions are less dramatic than in the case of EVs but still substantial. On a per-vehicle basis the reductions in pollutants are about 80 percent to 90 percent for CO, NOx, and VOC.[66]

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[62] Sierra Research Report No. SR93-06-01 (June 1993), “Leaving the Playing Field for Hybrid Electric Vehicles: Proposed Modifications to CARB's LEV Regulations,” cited from prepared testimony of James M. Lyons on behalf of WSPA (May 2, 1994).

[63] Bevilacqua-Knight, “1992 Electric Vehicle Technology.”

[64] Environmental Defense Fund, “ZEV and LEV Emission Bubbles: Taking the High Ground,” Washington, D.C., 1994.

[65] *Ibid*, p. 27.

[66] Ritchey, “Alternative Fuel Vehicle Penetration.”

Regardless of the potential for reducing pollutants, if EVs and AFVs replace conventional vehicles, the regulation plus mandates approach is not likely to be the most-effective means of reducing total air pollution for several reasons. First, new-car emissions standards are poorly targeted. They would do nothing to reduce the emissions from the millions of older, more heavily polluting vehicles already on the road. Second, the approach focuses on rates of emissions per vehicle and not total emissions, which does not recognize that the number of miles driven and fleet age are important variables. Third, emissions standards offer no economic incentive to reduce pollution beyond the limits set and take no account of the most efficient way of achieving reductions. Fourth, if new car prices rise to meet the mandates, through both better emissions controls and cost-shifting to pay for EVs, people will keep their older and dirtier cars. For all four reasons, the costs of removing pollution through this approach are high.

These are the same reasons that led DRI/McGraw-Hill[67] to estimate that emissions levels will remain essentially unchanged through the end of the century. CARB has itself estimated that the net effect of the electric vehicle mandate will be to remove less than 1 percent of smog precursors (NOx and VOCs). The net effect of introducing AFVs is less certain, since there is not yet a mandate for their use.[68]

There is no significant difference between the NOx emissions of Natural Gas vehicles (NGVs) and gasoline-fueled vehicles.[69] The uncontrolled NOx emissions of both gasoline and natural-gas-fueled vehicles are substantially in excess of applicable NOx standards. Similar to gasoline-fueled vehicles, NGVs can meet the standards with adequate compliance margins only through the installation of emission control systems.

Any emissions benefits associated with increased NGV sales will be due to the absence of evaporative and refueling emissions. However, Sierra's analysis indicates that the magnitude of these benefits is relatively small and the cost-effectiveness of achieving these benefits is not favorable. It should also be noted that, in the future, owners of heavy-duty natural gas vehicles may be allowed to generate marketable NOx emission credits to delay compliance with stationary source regulations or offset emissions from other sources.

The introduction of natural gas vehicles involves challenges related to on-board storage, range, and vehicle price. The cost of on-board storage is the major barrier to compressed natural gas vehicles. The size and weight of the storage containers limit the typical range of a compressed natural-gas vehicle to about 150 to 200 miles. Although the technology of natural-gas vehicles is proven, some risks in storage technology and durability-related design problems still exist. The limited emission benefits and the barriers illustrated are not favorable to the market success of natural-gas vehicles.

C. Air Pollution Reductions from Reformulated Gasoline

California Phase II reformulated gasoline will result in reductions in emissions of volatile organic compounds, oxides of nitrogen, carbon monoxide, and sulfur dioxide through a substantial reduction in both evaporative and exhaust emission from motor vehicles and emissions from petroleum marketing operations. Its potential for emissions reductions at relatively low costs is worth noting (see Table 1).

A major strength of reformulated gasoline as a means to alleviating mobile source emissions is that it can be produced, distributed and marketed in a cost-effective manner. Because it can be used in currently available vehicles and distributed through the existing gasoline distribution system, the effects of its use will be immediate.

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[67] *Economic Consequences of Adopting California Programs for Alternative Fuels and Vehicles*, Washington: DRI/McGraw-Hill and Charles River Associates.

[68] Sierra testimony, March 21, 1994.

[69] P.J. Mitchell, and P.A. Mulawa, “Environmental Potential of Natural Gas Fuel for Light-Duty Control Strategies and Fuel Consumption,” Society of Automotive Engineers, SAE Paper 932744, cited from prepared testimony of James M. Lyons on behalf of WSPA, May 2, 1994.

Atlantic Richfield Co. (ARCO) will spend $230 million in 1995 in addition to more than $200 million spent in 1994 to produce reformulated gasoline. In early 1996, ARCO is expected to have ECX that will meet a stricter state mandate available at service stations. Availability, effectiveness, and low cost are advantages of reformulated gasoline compared to other alternative fuels.

During the past two decades, there have been considerable advances in gasoline-powered internal combustion engines (ICEs), ICE-related emission control systems, ICE materials of construction, and fuels and lubricants, with most advances occurring in the past ten years. The introduction of exhaust gas recirculation to reduce exhaust gas emissions in 1972, the oxidizing catalysts to reduce hydrocarbon (HC) and CO in 1975, and the second generation catalyst (3-way catalyst) resulted in dramatic emissions reductions as stated above.

Low-emission technology will continue to improve to further reduce exhaust emissions. Between the 1996 and 1998 model years, fuel atomization and combustion are expected to improve through air-assisted or heated-tip fuel. New catalysts such as electrically heated catalysts, hydrocarbon traps or other new catalysts will greatly reduce cold-start emissions (accounts for approximately 15 percent of emissions on an average trip). Double-walled insulating exhaust systems and close-coupled catalysts will further reduce emissions.

The expected lower operating and maintenance costs of EVs compared to conventional vehicles is further challenged as the technologies of internal combustion engines continue to advance, enabling manufacturers to expand the intervals between scheduled maintenance requirements. It is also likely that at least the first generation EVs will have annual service requirements for inspecting power electronics and batteries.

D. Air Pollution Reductions from Electric Buses

SCAQMD requires that at least 30 percent of all buses in the Los Angeles basin be converted to very low emission vehicles over the next decade. In practice, this means that they must be electric, because other currently available bus technologies cannot meet the emission requirements. However, the MTA Board of Directors has deferred electrification because of the high cost.[70]

There is also a *de facto* requirement that attempts be made to acquire transit vehicles from local manufacturers. This is evident from the Calstart and Project California programs targeted at creating a local transit vehicle industry, as well as an infamous incident involving a Japanese manufacturer of light rail cars.

Because of the high cost of the infrastructure required to electrify bus lines, and the cost premium for buying electric buses, implementation of an electric bus program would raise operating costs. The cost premium for the purchase of such buses may be as high as 50 percent. Substituting electric buses for diesel buses will require a tradeoff of three diesel buses for every two electric buses under the best route conditions, and perhaps as high as 2:1 under the worst route conditions.[71]

Considering only the bus lines best suited for electrification, and assuming current funding levels, a move to require any alternative fuel would eliminate some transit vehicles. The worst case would be complete electrification of these lines, which would eliminate 91 vehicles. Put another way, it would cost the same for purchase and operation of 285 diesel buses as 194 electric buses. A switch to any alternative fuel would eliminate far fewer buses. For equal funding, the MTA could run 272 methanol buses or 268 natural-gas buses.[72]

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[70] Rubin, Personal correspondence dated March 31, 1994.

[71] *Ibid.*

[72] *Ibid.*

Since 1985, the experience of the RTD (now MTA) in Southern California has been that fewer vehicles and higher fares translate into lower ridership. Former bus riders shift to automobiles. The California Air Resources Board estimates that automobile passenger-miles result in 33-percent greater emissions than do diesel bus passenger-miles.[73] Even though there would be fewer diesel buses on the road, with more cars in use, total emissions would increase.

VI. ECONOMIC IMPACTS OF ALTERNATIVE FUELS AND ELECTRIC VEHICLE MANDATES

Harrington and Walls[74] estimated the cost-effectiveness of several emissions reductions strategies (Table 1). The cost per ton of volatile organic compounds (VOCs) removed varies from $1,900–$5,100 per ton for reformulated gasoline, $4,500–$6,000 for better inspection and maintenance, $12,000–$100,000 for alternative fuel vehicles, and $2,200–$41,000 for California's proposed low-emission vehicles. In contrast, the cost per ton of pollutant removed by higher registration fees based on emissions is estimated at $1,650, by higher gasoline taxes at $4,500, and by accelerated vehicle retirement at $4,000–$6,000 per ton.[75]

DRI/McGraw-Hill[76] also estimated the costs of removing hydrocarbons and nitrogen oxides via similar strategies. The projected cost range per ton of pollutants removed is $14,000–$30,000 for reformulated gasoline and tighter tailpipe emissions standards versus a range of $48,000–$292,000 for EVs and alternative fuels. Turning to the impact of mandating electric vehicles and alternative fuels on the California economy, the added expense of alternative fuels and vehicles will cost a family of four from $160 to $1,030 per year. This will result in lower expenditures for other goods and services; personal incomes may fall by $4.8–14.5 billion. The impact on tax receipts is estimated to be $1.0–2.8 billion up to the year 2010, mainly due to reduced gasoline taxes.

On the benefits side, impacts are difficult to quantify. Henderson and Rusin[77] survey the results of six valuation studies and find ranges for estimated benefits on the order of 90:1 for sulfur oxides, 150:1 for nitrogen oxides, 20:1 for carbon dioxide, 135:1 for particulates, and 5:1 for VOCs. In each case the highest values were produced by the SCAQMD[78] and appear to be outliers. If the SCAQMD study is dropped, the ranges fall to 20:1 for SOx, 6:1 for NOx, 20:1 for CO2, 36:1 for PM10, and almost 1:1 for VOCs. It appears that agreement on the valuation of benefits is unlikely.

In an attempt to estimate where the potential for consensus lies, Henderson and Rusin adopted conservative estimates for all of these pollutants (valuations toward the high side of the ranges) that tend to favor emissions reductions produced by electric vehicles. The valuations, in dollars per ton, multiplied by the difference in emissions between EVs and conventional vehicles, produces an estimate of the benefits per vehicle. Henderson and Rusin's calculations result in an annual benefit per vehicle of $167 per year. Even if these benefits estimates were grossly underestimated, they would not approach the

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[73] *Ibid.*

[74] Harrington et al., “Shifting Gears.”

[75] *Ibid.*

[76] *Economic Consequences of Adopting California Programs for Alternative Fuels and Vehicles*, Washington: DRI/McGraw-Hill and Charles River Associates, 1994.

[77] Henderson, et al., “Electric Vehicles,” p. 46.

[78] SCAQMD (with Southern California Association of Governments), *Air Quality Management Plan: South Coast Air Basin, SCEP.* 1994. Southern California Economic Partnership, Los Angeles: Southern California Association of Governments, 1989.

additional cost of buying, servicing, and operating an EV. As a result of these calculations, Henderson and Rusin[79] calculate a net social cost of adopting EVs in the range of $6,600 to $10,600 per vehicle.

These figures suggest that mandating EV use would not be cost-effective. Their absence from the market is not the result of any oversight or misunderstanding by automakers. Even when nonmarket benefits such as environmental effects are factored in, there is no evidence that EV mandates make economic sense. The opposite is true: when policy options are ranked by cost-effectiveness (as in Table 1), EVs rank at or near the bottom.

VII. CONCLUSIONS

Although air pollution remains a problem in many metropolitan areas, and automobiles are a major source of this pollution, it is very doubtful that EV mandates are a cost-effective approach. There are many more productive means of reducing automobile emissions, including efforts to accelerate the scrapping of older, polluting vehicles, mobile emissions testing, improvements in emissions technology (e.g. pre-warmed catalytic converters), cleaner fuels (e.g. reformulated gasoline), and AFVs other than electric-powered.

In any event, market incentives can achieve much more at less cost than government mandates. This would provide a framework in which the most effective pollution-control technologies would be determined by, say, the automobile manufacturers under a regime that assigned emission-reduction targets to them but would offer emission credits for the sale of super-clean cars. A market approach could also permit regional differentiation in emission-reduction goals, a possibility ruled out by the prevailing uniform standards approach.

In the current state of technology, EVs are not competitive with conventional motor vehicles in terms of the characteristics most desired by consumers, such as price, performance, range, comfort and size. If technological advances occur, we have no objection to expansion of the EV market, provided that EVs pass the test of consumer sovereignty.

Even if the EV market were to expand significantly, it will make little difference to the overall pollution problem. In some parts of the country, the pollution costs of coal- and oil-fired power generators will substantially offset vehicle emissions. Without a major advance in battery technology, the combination of small market share and lower VMT per vehicle implies that pollution savings will be modest. Of course, there is a small market niche that can be filled. Given the size of the California market and the heterogeneity of tastes, there will be some purchasers of EVs, especially if the degree of cross-subsidization is high enough to make EVs affordable. Some people bicycle to work, some writers use No. 2 pencils or typewriters rather than computers, and some people will drive AFVs, including EVs.

The future of the EV market, whatever it might be, should be left to the private sector; and the role of government should be minimal. The costs of wrong turns and failed experiments (like the rewards of success) should be borne by private investors not the taxpayers.

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[79] Henderson, et al., “Electric Vehicles,” p. 48.

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