State of California
California Environmental Protection Agency

AIR RESOURCES BOARD

STAFF REPORT

2000 ZERO EMISSION VEHICLE PROGRAM BIENNIAL REVIEW

August 7, 2000

EXECUTIVE SUMMARY

In 1990, California embarked on an ambitious strategy to reduce vehicle emissions to zero. This objective was to be achieved through the gradual introduction of electric vehicles into the California fleet. Specifically, the Air Resources Board mandated that at least 2 percent, 5 percent and 10 percent of new car sales be zero-emitting by 1998, 2001 and 2003, respectively.

The Zero Emission Vehicle (ZEV) mandate for passenger cars has been adjusted twice since then, in 1996 and 1998. The underlying goal, however, has not changed. California remains committed to achieving zero emissions performance wherever feasible in the vehicle fleet. The challenge is determining ***how*** to achieve sustainable success in the field.

As evidence of the State's commitment, California has partially subsidized the introduction of battery electric vehicles through grants and fleet purchases. That support is expected to continue.

The rationale for California's commitment is simple. Zero-emission technology is necessary to achieve the State's public health protection goals. Health-based state and federal air quality standards continue to be exceeded in regions throughout California, and more areas of the State are likely to be designated as nonattainment with promulgation of the new federal eight-hour ozone standard. California's burgeoning population and robust economy mean continued upward pressure on statewide emissions. Manufacturing, power generation, petroleum refining, goods transport, home heating and cooling, personal mobility and a wide range of human activities all have direct air pollution consequences. Accomplishing zero emissions in any of these source categories (or portion thereof) mitigates their adverse impacts and protects human health.

Zero-emission technologies also transcend some of the persistent problems with conventional air pollution sources. Combustion-based engines are inherently higher emitting and prone to deterioration over time. Catastrophic failures are also a concern. Older gasoline-powered vehicles, for example, become gross emitters if their emission control systems fail. Combustible fuels also have significant "upstream" impacts. Refining, fuel storage and delivery all have associated emissions from both routine operations, accidents (breakdowns, fuel spills), and ongoing compliance problems (e.g., leaking underground tanks). Apart from upset conditions that may occur during electric power generation, zero emission vehicles have none of these vulnerabilities. A battery powered electric car will remain emission-free throughout its useful life.

Current ZEV Mandate

ARB regulations require that 10 percent of the new light-duty vehicles offered for sale in California for model year 2003 be zero emitting. This requirement applies to intermediate and large volume vehicle manufacturers only.

Manufacturers have significant flexibility in meeting the ZEV requirements. Auto companies can earn extra ZEV credits by introducing vehicles before 2003, thereby reducing their total obligation. Extra credit is also available for battery electric vehicles with more than a 100 mile range per charge. Manufacturers may also delay compliance by one year provided they produce two years' worth of ZEVs by the end of 2004. Finally, large manufacturers can satisfy up to 6 percent of the 10 percent ZEV requirement with near-zero emitting technologies, and intermediate manufacturers may meet the entire 10 percent obligation via that route (producing no electric vehicles at all).

Eleven auto manufacturers are expected to qualify as ***"intermediate"*** in 2003: BMW, Hyundai, Isuzu, Jaguar, Kia, Mazda, Mitsubishi, Rover, Subaru (Fuji), Volkswagen and Volvo. Six auto companies are expected to qualify as ***"large"*** in 2003: DaimlerChrysler, Ford, GM, Honda, Nissan and Toyota.

If no change is made to today's ZEV regulation, staff estimates that approximately 22,000 electric vehicles would need to be offered for sale in 2003 to meet a four percent ZEV requirement. However, this total could change significantly, up or down, based on each manufacturer's actual production decisions and their chosen compliance path. As noted above, early ZEV introduction or the use of additional vehicles with extended range would decrease the 2003 obligation. Reduced reliance on PZEVs, on the other hand, would increase the number of ZEVs needed.

The ZEV mandate continues in 2004 and each year thereafter. Again, if the rule is unchanged, staff estimates ZEV availability will grow gradually over time, reaching 31,000 to 78,000 units (4 percent to 10 percent) by 2006.

The September 2000 Biennial Review

When the ZEV mandate was adopted in 1990, electric vehicles were in a very early stage of development. To ensure successful implementation, the Board directed staff to report biennially on the status of technological progress. The September 2000 biennial review is the fifth in-depth examination of the technical and economic issues related to ZEVs. Since auto makers generally need three years' lead time for production, this biennial review is also the last significant opportunity to assess their readiness for meeting the 2003 requirements.

This report describes the current status of ZEV technology and the prospects for near- and long-term improvement. The analysis is based upon experience gained through the 1996 Memorandum of Agreement (see below), staff meetings with each of the affected manufacturers, contract work performed by outside experts, and extensive comments received at two public workshops conducted earlier this year.

1996 Memorandum of Agreement

The original ZEV mandate called for 2 percent penetration in 1998 (approximately 20,000 vehicles). However, in 1996, the ARB determined that a smaller introduction was warranted given the status of electric vehicle technology at the time. Accordingly, the ARB's Executive Officer entered into Memoranda of Agreement (MOAs) with large volume manufacturers to produce a limited number of ZEVs, specifically 3,750 vehicles between calendar years 1998, 1999 and 2000. Multiple credits for advanced batteries reduced the total legal commitment to just over 1,800 electric vehicles.

Today there are approximately 2,300 electric vehicles on the road in California. The products are highly attractive, high performing and range in style from vans, pick-up trucks, sport utility vehicles and station wagons to two-seater sports cars. All of these electric vehicles were introduced within the last four years. The only significant gap is the absence of a 4-door, 5-passenger ZEV sedan, which no manufacturer is currently producing.

Although the market is just forming, customer interest is encouraging and suggests that additional demand exists for ZEV products. Unfortunately, the full extent of this demand cannot be quantified because very few electric vehicles are available. Those manufacturers who have met their quotas have largely ceased production. Companies still making ZEVs have encountered production delays and are mostly marketing to fleets. This virtual “black out” condition was not anticipated when the MOAs were signed in 1996. It also complicates staff's analysis of market readiness for 22,000 ZEVs in 2003. When even the most motivated customers cannot obtain electric vehicles, the ability to gauge broader consumer interest and acceptance are severely diminished.

The primary reason for the “black out” is cost. Manufacturers are not yet able to produce a competitively priced electric vehicle without incurring significant losses on each unit leased or sold. The secondary reason is uncertainty. Car companies are unwilling to invest in volume production until they see the business case for each ZEV model, a certain market, and a definitive regulatory signal from the State.

Implementation of Year 2003 Requirements

1. Vehicle Technology Assessment

There is no technological barrier to building battery powered ZEVs; the issue is cost and consumer acceptance. With regard to near-zero emission vehicles, technology exists which allows vehicles to achieve the required level of performance. Several manufacturers have stated, however, that due to lead time considerations they will not be able to build enough PZEVs to take full advantage of the partial ZEV option in 2003. If they cannot overcome those challenges, more battery electric vehicles will be needed to meet the 10 percent ZEV mandate. Hybrid vehicles are an environmentally attractive product and could achieve near-zero (PZEV) emissions performance in the near future. Finally, hydrogen powered fuel cell vehicles have potential to become an additional pure ZEV technology, but will not be commercially available by 2003. These conclusions are explained in more detail below.

Battery electric vehicles are clearly technologically feasible. Seven models are on the road including GM's EV1 2-seat sports car; the Chevrolet S-10 and Ford Ranger pick-up trucks; Honda's EV PLUS (a 4-seat, 2-door platform comparable to Honda's CRV), the Toyota RAV4 sport utility vehicle; Nissan's Altra EV station wagon; and the DaimlerChrysler EPIC minivan. In addition, several classes of smaller battery electric vehicles are emerging. These include low-speed vehicles (LSVs, also referred to as "neighborhood electric vehicles" or NEVs) and low-range vehicles designed for in-city driving (City EVs). Examples of the latter include the Ford TH!NK, the Toyota E-COM, and Nissan's Hyper-Mini. All of these vehicles qualify as ZEVs under the current ARB regulation.

Regarding PZEVs, the leading candidates are extremely clean gasoline-powered cars, with or without hybrid electric drive-train technology. To qualify for PZEV credit, a vehicle must be certified to the super ultra low emission level (SULEV) exhaust standards, have zero evaporative emissions, and come with a 150,000 mile warranty. To date, only the Nissan Sentra has achieved PZEV status. Three other vehicles (Honda Accord, Honda Civic GX, and Toyota Prius) have attained the SULEV criteria, but have not met the remaining requirements. Both large and intermediate volume manufacturers are concerned about their ability to overcome all the engineering challenges implicit in the PZEV criteria by 2003. If they cannot reach that objective, up to the full 10 percent of battery electric cars may be required. Staff concurs that the PZEV criteria are extremely challenging and that some manufacturers will be unable to take full advantage of the PZEV option in 2003.

Hybrid electric vehicles are the newest entrants to the advanced vehicle field. These vehicles combine batteries, a supplemental electric drive train, and a downsized conventional fuel tank to increase overall efficiency. Hybrid vehicles consume less fuel per mile of operation, thereby reducing upstream environmental impacts and releases of climate changing gases. Hybrid vehicles may also be low, ultra low or super ultra low emitting if they are designed to meet those respective exhaust standards. Two hybrid vehicles are currently available: the Honda Insight and the Toyota Prius. Although neither qualifies for PZEV credit at this time, there is no inherent technological reason why hybrids cannot achieve PZEV performance. The main obstacle is the time needed to design, test and perfect the necessary emission controls.

Fuel cell vehicle (FCV) technology has the potential to be zero emitting when powered by pure hydrogen from a relatively clean source. The California Fuel Cell Partnership is examining the potential for commercializing such technology, along with other FCV fuel types. A few prototype vehicles are available for testing and demonstration.

2. Battery Technology Assessment

Batteries are the single most expensive component of electric vehicles. For that reason, affordable battery packs--both today and when produced in volume--are crucial to achieving a sustainable electric vehicle market. ARB's existing regulations also place a premium on advanced (long-range) battery technology. This preference was based on early survey results and upon staff's judgment that electric vehicles with greater than 100 mile range will sell better, to more people and for more uses, than shorter range vehicles.

ARB contracted with a team of outside experts to obtain the best available information on battery advances, costs and future trends. The Battery Panel concluded that nickel metal hydride (NiMH) batteries were the most promising advanced technology, having both high performance and the longest useful life. Unfortunately, the Panel also concluded that battery costs are high and will not meet cost-competitive targets for some time. Although volume production will help, a breakthrough is needed to achieve truly affordable NiMH packs.

Several commenters have suggested that ARB revisit its preference for advanced battery technology. Lead acid (PbA) batteries, they suggest, could meet market needs at a far lower cost. Their justification is two-fold. First, several EV drivers testified at staff workshops that that their actual driving needs were lower than they anticipated before they leased a ZEV and that they would not pay a premium for greater range. In addition, some auto manufacturers are closely examining the business case for lead-acid based City Cars that would be overtly marketed as limited range, niche vehicles. The opposing view is that advanced batteries meet a broader range of driving needs, produce less waste (since they last longer), and may ultimately serve a larger consumer market.

3. Infrastructure Assessment

Unlike conventional vehicles, battery powered ZEVs do not require an extensive "fueling" infrastructure since most customers will recharge at work or at home. The availability of public charging stations is nonetheless extremely important because of its influence on consumer confidence and acceptance. Public chargers also enable ZEV owners to drive longer distances, and to reach more destinations than they otherwise might.

The public infrastructure for electric vehicles continues to expand in California. Currently, there are about 400 public charging stations statewide with approximately 700 separate chargers. Most of these were constructed with a combination of government and electric utility funds. Recently, a few private companies have begun to offer electric charging services to their customers. The most notable example is Costco, which has a corporate-wide "all electric" philosophy. Staff expects these services to expand as additional local governments and private companies embrace electric vehicle technologies.

The most difficult issue affecting public charging infrastructure is the absence of uniform charging standards or equipment. A little more than half of the chargers are inductive; the rest are conductive. Current vehicles use a 220 volt system. When City Cars come to market, they will introduce the need for a new minimum voltage of 110. There is no easy way around this dilemma. Because the chargers are integrally linked to vehicle design and have competitive characteristics, manufacturers are unwilling and may actually be unable to move toward full standardization.

Fast charging has been successfully demonstrated in the DaimlerChrysler EPIC minivan and holds great promise for the future. However, there is a significant economic barrier: fast charging is more expensive per station and would require extensive financial support to implement. Fast chargers also require special battery packs that can receive rapid charging without producing excessive heat.

4. Market Assessment

There is significant disagreement over the extent of market demand for electric vehicles. Manufacturers assert that the lack of leases during the first years when vehicles were available means that the market can only absorb a few hundred ZEVs per year. Electric vehicle advocates and fleet operators point to current waiting lists as evidence of strong customer interest and pent-up demand. Staff views this as the most difficult area in which to develop reliable estimates. The entire market is new and product availability has been constrained such that true consumer interest is exceedingly difficult to gauge.

The recent emergence of fundamentally new ZEVs–namely city cars and neighborhood EVs–further complicates staff's assessment. Although the business case for inexpensive, in-town EVs appears to be promising, there is as yet no market experience for selling these products in the U.S. Manufacturers will have to start from scratch in building consumer awareness and interest.

Left unchanged, the current ZEV requirement will result in approximately 22,000 electric vehicles by 2003. That represents almost a ten-fold increase over the number of ZEVs on the road in California today. The quantity of ZEVs will grow in 2004, 2005 and 2006 as ZEV production ramps up per the current ARB regulation. Whether all of these vehicles can be successfully marketed and placed is a key issue facing the Board.

Studies and surveys indicate that the primary factors affecting EV market demand are range, recharge time and competitive pricing. Based on experience to date and public testimony, staff has identified several other factors that are critical to ongoing success. The single greatest need is for near term ZEV availability, followed by a smooth, orderly buildup from the current base. Other important factors include public infrastructure, additional vehicle platforms, public education (including real time information on available products, subsidies, station locations, and how to go about obtaining a ZEV), and making all ZEV products available to retail customers.

Cost Estimates

Today’s ZEVs are more costly for manufacturers to make than any other vehicle technology being produced for sale between now and 2003. As noted above, most of that cost differential stems from the battery pack. The cost gap will narrow as technology improves and manufacturers move to volume production. However, there is no getting around the fact that near-term ZEVs will be relatively more expensive to produce. Staff estimates that the incremental costs for ZEVs in 2003 will range from $7,500 for City EVs, up to more than $20,000 for freeway capable ZEVs with advanced NiMH batteries. These calculations exclude the costs incurred for research and development of each ZEV model.

Under an optimistic but nonetheless plausible scenario, battery EVs could become cost-competitive with conventional vehicles on a lifecycle cost basis. This scenario assumes volume production of more than 100,000 ZEVs.

It is important to distinguish cost from price. Staff has estimated the cost of ZEV production to manufacturers, and the cost of operating ZEVs over their useful life. That is not the same as estimating the price at which various electric vehicles would be offered for sale. Price is set in a competitive environment and can differ from cost for several reasons. In initial years, manufacturers will not be able to recover the full cost of ZEV production through prices alone. This shortfall will be wholly borne by the automakers unless California offers full or partial subsidies to mitigate the revenue gap.

During the MOA period, California provided $5,000 per vehicle “buy down” grants to offset the higher incremental cost of producing ZEVs. These grants were given to the auto manufacturers, who applied them as a discount to their ZEV lease or purchase prices. With some exceptions, the $5,000 grants were funded fifty/fifty by the California Energy Commission and local air pollution control districts. CEC’s funding for this program came from the State’s Petroleum Violation Escrow Account (PVEA), while districts have relied upon their motor vehicle registration fee surcharge revenues. Subsidies of up to $500 were also available for the installation of individual, at-home charging stations. Both of these financial incentive programs are funded only through FY 2000-2001.

To support a significantly higher penetration of ZEV vehicles, California will need to continue its subsidy programs–at least through the initial years. It will also be necessary to identify an alternate fund source. The State’s entire PVEA account will be exhausted by the end of next year. Moreover, local air districts have multiple, competing claims on their vehicle registration fee revenue (including heavy-duty diesel clean-up programs) and are unlikely to be able to continue to allocate large amounts to ZEV subsidies.

Environmental, Energy and Economic Benefits

ZEVs provide comprehensive environmental, energy and societal benefits.

With respect to the environment, ZEVs are the “gold standard” for vehicular air pollution control. They reduce both criteria and toxic pollutant emissions to the maximum feasible levels. High-efficiency ZEVs and hybrid electric near-ZEVs also cut emissions of carbon dioxide and other greenhouse gases. Finally, ZEVs minimize the multi-media impacts of vehicle operation, eliminating the need for a whole host of upstream petroleum refinery, storage and delivery activities. Admittedly, ZEVs have their own upstream impacts related to power generation and create new waste disposal issues. However, on an overall lifecycle basis, they are environmentally superior to conventional automobiles. As California’s power generation system becomes increasingly cleaner, so too will the upstream emissions associated with ZEVs.

Regarding energy use, vehicles powered by grid electricity increase the diversity of California’s transportation energy system. This reduces the State’s dependence on foreign oil and contributes to greater stability in the overall transportation fuels market. Advanced battery ZEVs and hybrid electric near-ZEV technologies are also highly efficient; reducing absolute energy demand per mile of vehicle operation. Finally, ZEVs have the potential to be powered by renewable sources of energy such as wind, hydropower or solar energy.

The societal benefits of ZEVs include their clean, quiet operation in neighborhoods and on city streets. ZEVs can also benefit the State’s economy. Because of their high technology leadership, California companies have the technical and scientific capability to play significant roles in the design, development and production of advanced technology zero emission components and vehicles.

In public comments, automakers stated that the direct air quality benefits of the ZEV program are minor and, therefore, not worth the investment in electric cars. Staff recognizes that in the near-term, due to the small penetration of ZEVs and corresponding improvements in conventional cars, fleet-wide benefits will be modest. However, this is a long-term strategy. On a per vehicle basis, ZEVs are significantly cleaner than even the cleanest gasoline-powered alternative. They will steadily reduce emissions as their fleet penetration grows. Even more importantly, ZEVs have no risk of in-use emission control system failures. They are the only technology that is guaranteed to *permanently* reduce emissions over time.

Conclusion

California has made significant technological progress toward its zero emission objectives. More than two thousand battery EVs are on the road, illustrating that ZEVs can be built and deployed. There are a variety of attractive ZEV platforms. Also, their respective characteristics meet a wide range of market applications including fleets, small businesses and private commuting. While electric vehicle range is limited and recharging times are long, ZEVS are in everyday use in many different circumstances across the state. All evidence and testimony points to the fact that those who are using today's EVs are very pleased with their performance.

Progress has been less pronounced on the economic side. Staff's cost analysis concludes that both the initial and lifecycle costs of battery EVs will significantly exceed those of comparable conventional vehicles in the 2003 timeframe. However, in volume production and with improved technology, battery EVs could become competitive on a lifecycle cost basis.

The near term cost premium for ZEVs is not surprising since every incremental step in pollution control provides benefits at a higher marginal cost. The ZEV program, moreover, is not a typical step-wise adjustment but a transformative leap forward. Given the sweeping nature of ZEVs' environmental, energy and societal effects, it is reasonable to expect that the program will be more expensive in its early years than more limited measures. At the same time, the fact that costs impose burdens must also be acknowledged. While higher costs persist, state subsidies could be very important to mitigate impacts on auto manufacturers and to nurture a growing ZEV market.

The market for battery EVs is just starting to be understood and is very difficult to quantify. As noted above, the 2003 ZEV mandate represents a ten-fold increase in the number of actual battery EVs on the road. Placing all of those vehicles within a year or two and sustaining those sales in 2004, 2005 and beyond is a significant marketing challenge by anyone's measure.

Staff has identified a number of applications that are well suited to using ZEVs and which could absorb several thousand units. Actual vehicle sales/leases will depend on consumer awareness and interest, available products and their net market price (minus any subsidies or tax incentives that may be provided). These factors suggest that much more extensive public education is needed. In addition, continuity of ZEV production is critical. Market acceptance cannot build, and volume production cannot be achieved, if ZEVs continue to be available only in boom and bust cycles.

The 1996 MOA was a highly collaborative effort between the State of California, automakers, public utilities, local governments, fleet operators and many private ZEV enthusiasts who put their own dollars on the line. As ZEV penetration grows, this partnership needs to continue and expand. Teamwork among all the interested parties will increase the probability of success and hasten the advent of a truly self-sustaining ZEV market.

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1. INTRODUCTION

1.1 Background

Air quality in California has improved dramatically over the past 25 years, largely due to continued progress in controlling pollution from motor vehicles. Faced with ever more stringent regulations, vehicle manufacturers have made remarkable advances in vehicle technology. Several thousand zero-emission vehicles are now in everyday service on California roads, and the latest conventional internal combustion engine vehicles achieve emission levels that seemed impossible just a few short years ago.

Despite this progress, however, air quality in many areas of the state still does not meet federal or state health-based ambient air quality standards. Mobile sources still are responsible for well over half the ozone-forming emissions in California. The relative contribution of passenger cars and small trucks is expected to decline over time as new standards phase in , but in 2020 such vehicles will still be responsible for about 10 percent of total emissions. State and federal law requires the implementation of control strategies to attain ambient air quality standards as quickly as practicable.

Mobile sources are also the primary source of emissions of toxic air contaminants in California, and a major contributor to greenhouse gas emissions. The facilities needed to refuel the current vehicle fleet (service stations, bulk terminals, refineries) are significant sources of smog precursors, air toxics, water pollution, and hazardous waste.

1.2 The Zero Emission Vehicle Program

The Zero Emission Vehicle (ZEV) program was originally adopted in 1990, as part of the first ARB Low-Emission Vehicle regulations. The ZEV program is an integral part of California's mobile source control efforts, and is intended to encourage the development of advanced technologies that will secure increasing air quality benefits for California now and into the future. ZEVs have significant long-term benefits because they have no emission control equipment that can deteriorate or fail, and generate only minimal "upstream" refueling and fuel cycle emissions.

Under the 1990 regulations, the seven largest auto manufacturers were required to produce ZEVs beginning with model year 1998. In model years 1998 through 2000, two percent of the vehicles offered for sale in California by large volume manufacturers were to be ZEVs, and this percentage was to increase to five percent in model years 2001 and 2002, and ten percent in model years 2003 and beyond.

In 1996 the ARB modified the regulations to allow additional time for the technology to develop. The requirement for ten percent ZEVs in model years 2003 and beyond was maintained, but the sales requirement for model years 1998 through 2002 was eliminated. At that same time, the ARB entered into Memoranda of Agreement (MOAs) with the seven largest vehicle manufacturers. Under the MOAs the manufacturers must place more than 1,800 advanced-battery EVs in California in the years 1998 through 2000, and the ARB must work with state and local governments to help develop ZEV infrastructure and remove barriers to ZEV introduction.

In 1998 the ARB provided additional flexibility in the ZEV program by allowing additional types of vehicles to be used to meet program requirements. Under the 1998 amendments, manufacturers can use extremely clean advanced-technology vehicles (referred to as “partial” ZEVs) to meet the 10 percent ZEV requirement, except that large-volume manufacturers must, at a minimum, have 4 percent of their sales be vehicles classified as “full” ZEVs.

1.3 ARB Long-Term Vision

Simply put, continued reliance on today’s technology will not allow California to reach its health-based air quality goals. In ARB’s vision of the future, therefore, the entire vehicle fleet will produce zero tailpipe emissions, and will use fuels with minimal “fuel cycle” emissions (emissions that occur due to vehicle refueling and the related production or transportation of fuel). As an ancillary benefit to the advanced technologies employed, the future vehicle fleet also will be highly energy efficient, use diverse energy sources, and will result in reduced emissions of greenhouse gases. In considering the ZEV program, it is essential to keep this long-term perspective firmly in mind

In public comments, manufacturers have stated that they do not expect to see a zero emission fleet in any reasonable planning timeframe. Manufacturers do expect that in the future, global customer demands will reward companies that can meet society’s transportation needs while eliminating harmful environmental impacts.

1.3.1 Continued Emphasis on Zero Emissions

Battery-powered electric vehicles and other ZEVs such as hydrogen fuel cell vehicles hold distinct air quality advantages over technologies that use a conventional fuel such as gasoline in a combustion engine. High volatility liquid fuels such as gasoline are responsible for significant fuel cycle emissions. Vehicles with combustion engines inevitably exhibit deterioration that results in increased emission levels as the vehicle ages. They are also subject to becoming gross polluters if critical emission control systems fail. Although new vehicles have more durable emission control systems and on-board diagnostic systems that are effective in alerting owners to emission related problems, owners may not respond to failure signals promptly. The inspection and maintenance program will not capture vehicles that are operated without being registered, and repair cost limits may permit continued operation of some high emitting vehicles.

For all of these reasons, vehicles with no potential to produce emissions are the "gold standard" of even the cleanest, most advanced new technologies. The commercialization of ZEVs is critical to the long-term success of California's clean air program. Even with the full implementation of the LEV II program, emissions from light duty vehicles will still represent some 10 percent of total emissions in the South Coast Air Basin. Achieving the new air quality standards for particulate matter, not to mention the state ozone standard, will require further reductions. Taking into account the anticipated growth in the number of light-duty vehicles and the number of miles they travel each day, it is clear that we need to eliminate emissions related to vehicle deterioration and fuel use from a significant portion of the light-duty vehicle fleet. ZEVs can accomplish this goal.

1.3.2 Near-Zero Technologies Also Play a Major Role

The ZEV requirements have been instrumental in promoting battery, fuel cell, component and vehicle research and development. These requirements have also been successful in spawning a large variety of extremely low-emission vehicle technologies. Many of these technologies have at least some of the desirable qualities inherent to ZEVs, such as extremely low emissions of smog precursors and toxic air contaminants, reduced emissions of greenhouse gases, extended durability, or high efficiency.

Such vehicles will play a major role in achieving further air quality improvement. First of all, many of the technologies can be adopted at relatively low cost. For example, staff estimates the incremental cost of going from a SULEV to a PZEV to be about $500. Vehicles using these technologies thus have the potential for widespread early market penetration. Although the near-ZEV vehicles are not as clean as ZEVs, if produced in large numbers they provide a significant air quality benefit relative to the conventional vehicles that they replace.

Second, because many of these vehicles use components also found on zero emission vehicles (e.g. battery packs, controllers, and electric drive), volume production of near-zero vehicles will help reduce the cost of components used on zero emission vehicles and hasten their commercialization.

1.3.3 Linkage to Broader Issues

The mission of the Air Resources Board is to protect public health through the reduction of air pollution. The Board's primary focus is on the reduction of smog-forming pollutants and toxic air contaminants. To date, most discussion of ZEV air quality impacts has focused on their smog benefits.

In addition to their dramatic reduction in smog-forming pollutants, ZEVs also provide reductions in the emissions of toxic air contaminants. The benefits of reductions in toxic air contaminants are felt statewide. Recognizing that mobile source pollution from highway traffic may disproportionately affect nearby inner city and low-income neighborhoods, reductions in toxic emissions from motor vehicles can also help address community level public health concerns.

Above and beyond these traditional air pollution benefits, ZEVs can also make significant positive contributions in other environmental areas. For example, the use of alternative fuels can reduce the multimedia impact of fuel spillage on water quality, and can increase the diversity of California's energy supply. The smooth, quiet operation of electric drive vehicles can improve the quality of life in crowded urban areas. Electricity and hydrogen, which can be used to power ZEVs, can be produced from renewable resources such as solar, wind or hydropower, or biomass feedstocks. Thus these technologies can help pave the way towards a sustainable energy future.

Perhaps the most important ancillary benefit, though, is that high-efficiency ZEVs and hybrid electric near-ZEVs can lead to significant reductions in emissions of CO_2 and other greenhouse gases. The Air Resources Board does not currently regulate emissions of greenhouse gases. The Board is, however, working with the California Energy Commission to better understand the contribution of mobile sources to total greenhouse gas emissions, and quantify the climate change impact of various fuels and vehicle technologies. Even in the absence of specific regulatory requirements it is clear that, other things being equal, technologies that achieve lower greenhouse gas emissions are the preferred alternative. Meanwhile, auto manufacturers worldwide are working to reduce greenhouse gas emissions from their vehicles in keeping with the Kyoto Protocol and other requirements in place or pending in other markets.

ZEVs can benefit California's economy as well as our public health. Because of their high-technology leadership, California companies have the technical and scientific capability to play a significant role in the design, development and production of advanced technology zero emission components and vehicles. ARB is currently developing estimates of some of the economic benefits of the ZEV program.

ZEVs thus have the capability to provide comprehensive environmental, energy and societal benefits. While the Board's consideration of the ZEV regulation is firmly rooted in its air quality mandate and authority, the Board is aware of the multi-faceted effects of its policy choices. Over the long term the Board, in cooperation with its sister agencies, will devote increasing attention to an integrated consideration of such broader issues.

1.4 Progress Since the 1998 Biennial Review

Perhaps the best way to characterize progress over the two years since the last Biennial Review is to say that EVs have rapidly moved into widespread real world applications.

In July of 1998, when the last Biennial Review staff report was released, manufacturers had just introduced their vehicles. On March 29, 2000, numerous enthusiastic EV drivers arrived en masse in their leased vehicles to testify at the ZEV Review workshop in Sacramento. Others arrived in rental electric vehicles they had picked up at the Sacramento airport. On that same day, dozens of EVs were at work elsewhere in the Sacramento area for a variety of state and local agencies. Down Interstate 80 in West Sacramento, plans were underway for a groundbreaking ceremony for the headquarters of the California Fuel Cell Partnership. In Los Angeles, electric minivans were in use shuttling passengers to and from Los Angeles International Airport. In Yosemite Valley, two electric vehicles provided zero emission mobility for park staff and visitors. In the Bay Area, San Diego, Ventura, the Gold Country, the San Joaquin Valley, Los Angeles, and elsewhere around the state, electric vehicles were in daily use. Some specific highlights of recent progress include:

- More than 2,300 electric vehicles in a variety of configurations have been delivered for lease or sale in California.
- All of the required MOA vehicles produced to date have been successfully leased. At present there are more interested customers than there are vehicles available.
- General Motors has released the “Generation II” NiMH version of the EV1, featuring a range of 142 miles, and a NiMH version of the S-10 pickup.
- DaimlerChrysler released a NiMH version of the EPIC minivan. EPIC minivans using fast charge are in daily use by Xpress Shuttle serving passengers at Los Angeles International Airport.
- Ford has released a NiMH version of the Ranger pickup.
- Ford has created a Th!nk subsidiary to market advanced technology vehicles, and has announced plans to market City and neighborhood sized EVs.
- Ford introduced an innovative and successful program to market the EV Ranger to schools and parks at a reduced rate of $199 per month.
- The United States Postal Service has ordered 500 electric vehicles, based on the Ford Ranger platform, for mail delivery in California.
- Honda has begun to re-market vehicles after the expiration of the original three year lease, resulting in additional zero emission miles of service. Most of these vehicles are being re-leased by the original drivers, giving evidence of high customer satisfaction.
- Toyota has introduced vehicles with a second generation, smaller, inductive charging paddle.
- Nissan has introduced the first electric vehicle powered by lithium-ion batteries.

- Nissan has introduced a Sentra vehicle that meets partial ZEV credit requirements.
- Manufacturers have continued to refine and improve power control electronics, electric drivetrains, and other components. For example, General Motors is developing a Generation III electric drivetrain.
- Southern California Edison operates a fleet of 320 EVs, which has logged more than 3.5 million miles of service.
- As of July 1, 2000, electric vehicles that have secured the appropriate permit sticker from the California Department of Motor Vehicles are authorized to travel in High Occupancy Vehicle lanes regardless of the number of occupants.
- Under recent legislation, the registration fee paid by electric vehicles is now no greater than that of a comparable conventional vehicle.
- More than 120 public fleets around the state have used EVs under the ARB's Electric Vehicle Loan Program, and several California utility companies have conducted highly successful loan programs within their jurisdictions.
- State and local government fleets have made major purchase commitments.
- EVs are available for rent at the Los Angeles, Ontario and Sacramento airports and in Beverly Hills, and will soon be available at the Burbank and Orange County airports as well as downtown Sacramento.
- Significant public infrastructure continues to be installed around the state.
- The California Fuel Cell Partnership has been formed, with the goal of demonstrating fuel cell vehicle technology and alternative fuel infrastructure over the next four years.
- Automakers and the public sector have supported the ZEV program with significant incentives for vehicles and for infrastructure.

1.5 The 2000 Biennial Review Process

When the ZEV requirement was adopted in 1990, low- and zero-emission vehicle technology was in a very early stage of development. The Board acknowledged that many issues would need to be addressed prior to the implementation date. Thus the Board directed staff to provide an update on the ZEV program on a biennial basis, in order to provide a context for the necessary policy discussion and deliberation. The next biennial review of the ZEV program is scheduled for September 2000.

The ARB is committed to working closely with all interested parties to ensure that they have an opportunity to provide comments and suggestions throughout the review process. The key milestones of the review process have been as follows:

March 29, 2000	Public Workshop Background Information for the September Review Sacramento
March 30, 2000	Public Workshop Multi-Manufacturer Ownership Arrangements

	Sacramento
May 31-June 1, 2000	Public Workshop Background Information for the September Review Diamond Bar
August 7, 2000	Staff Report released to the public
September 7, 2000	Board Meeting

1.6 The Purpose of This Document

In preparing for the Board's upcoming Biennial Review, the goal of the staff is to provide a thorough, accurate portrayal of the current status of ZEV technology and the prospects for improvement in the near- and long-term. Staff efforts have included meetings with vehicle manufacturers, environmental groups, and other interested parties, on-site visits to the large vehicle manufacturers in Japan and in Michigan, discussions with EV drivers, and research on current and pending technologies and their environmental impacts. ARB also has contracted with outside technical experts to review the state of battery technology and production costs, and assess the full fuel cycle emissions and energy efficiency of various vehicle types and fuel sources.

This document is descriptive rather than proscriptive—it does not draw conclusions or make recommendations. Rather, the purpose of this Staff Report is to put forth technical information, and provide a framework and context for the Board's consideration of the relevant issues.

1.7 Public Comments

At the March 2000 public workshop, three public comment sessions were conducted. These sessions addressed the preliminary staff assessment, the EV driver experience, and advances in ZEV technology. Seventy-three individuals testified at the workshop, and staff received nearly forty additional written submittals. At the May 2000 workshop, sessions addressed the EV market, the report of the Battery Technology Advisory Panel, environmental benefits, and cost. More than 100 individuals testified, and numerous separate written submittals have been provided.

In seeking public comment, staff hoped to identify areas where the staff report could be strengthened or improved, and bring to light issues that the public believes should be highlighted for the Board's consideration. The extensive public comment provided has been valuable during preparation of this Staff Report. Information provided as part of public comment is incorporated or noted as appropriate throughout the body of the Staff Report.

2 MANUFACTURER STATUS

2.1 Introduction

The ZEV requirement applies to large and intermediate volume manufacturers (defined below). Beginning in model year (MY) 2003, at least 10 percent of the passenger cars and light duty trucks below 3,750 pounds gross vehicle weight produced and delivered for sale in California by large and intermediate volume manufacturers must be ZEVs. An intermediate volume manufacturer may meet this ZEV requirement entirely with partial ZEV allowance vehicles (defined in Section 4.3.1) or credits generated by such vehicles. A large volume manufacturer must meet at least 40 percent of its ZEV requirement with pure ZEVs, full ZEV allowance vehicles, or credits generated by such vehicles. Large volume manufacturers may, at their option, meet the remaining 60 percent of their ZEV requirement with partial allowance vehicles or credits generated by such vehicles. A small volume manufacturer is not required to meet the percentage ZEV requirements, but may earn and market credits for the ZEVs or ZEV allowance vehicles it produces and delivers for sale in California.

2.2 Manufacturer Volume Classifications

Because MY 2003 is quickly approaching and production planning is well underway, ARB staff has attempted to establish each manufacturer’s volume classification and, thus, each manufacturer’s ZEV requirement.

For purposes of classification for 2003, small volume manufacturers are defined as those with California sales below 4,500 per year, using the average number of vehicles sold over the preceding three years. Small volume manufacturers are not subject to the ZEV requirement. Based on current production and sales data, ARB staff expects the small volume manufacturers in MY 2003 to be the following:

- Dae Woo
- Ferrari
- GFI
- Lamborghini
- Lotus
- Porsche
- Rolls Royce
- Saab
- Suzuki

Intermediate volume manufacturers are defined for 2003 as those with California sales between 4,501 and 35,000 light and medium duty vehicles per year, again averaged over the preceding three years. Based on the same data, ARB staff expects the intermediate volume manufacturers in MY 2003 to be the following:

- BMW
- Subaru (Fuji)
- Hyundai
- Isuzu
- Jaguar
- Kia
- Mazda
- Mitsubishi
- Rover
- Volkswagen
- Volvo

Large volume manufacturers are defined as those that are not small volume manufacturers or intermediate volume manufacturers. Based on the same data, ARB staff expects the large manufacturers in MY 2003 to be the following:

- DaimlerChrysler
- Ford
- GM
- Honda
- Nissan
- Toyota

During public comment at the March workshop, one manufacturer recommended that the minimum annual sales threshold for a large manufacturer be increased above the current level of 35,000. This manufacturer noted that automakers just above this cutoff are far more limited in resources than the existing large manufacturers, who typically have annual California sales of at least 100,000 and often substantially more. Another manufacturer made a similar recommendation, with similar reasoning, regarding the minimum annual sales threshold for an intermediate volume manufacturer, currently set at 4,500. Representatives of several intermediate volume manufacturers testified that due to constraints imposed by the planned dates for introduction of new engines and vehicle platforms, they would not be able to produce the required number of PZEVs as early as 2003.

2.3 Potential Classification Changes

Although previously categorized as a large-volume manufacturer, Mazda has consistently been selling fewer than 35,000 vehicles in California in recent years. Mazda will be considered an intermediate volume manufacturer beginning in MY 2003 if its production volume remains at the current level.

BMW and Volkswagen have each been selling approximately 35,000 vehicles per year in California in recent years. If their 2000 through 2002 MY average sales exceed 35,000, they will need to meet ZEV requirements as large volume manufacturers beginning in MY 2006.

Subaru, which is currently considered an intermediate volume manufacturer, has been selling near the lower limit of the intermediate volume manufacturer classification in California in recent years. Therefore, depending on its actual sales in model years 2000 through 2002, Subaru may be classified as either an intermediate or a small volume manufacturer in MY 2003.

In 1998 Isuzu produced only light duty trucks between 3,751 and 5,750 pounds gross vehicle weight (LDT2s), which are not subject to the ZEV requirement. Rover produced only medium duty vehicles, also not subject to the ZEV requirement. Therefore, although Isuzu and Rover are intermediate volume manufacturers, they will not need to produce any ZEVs in MY 2003 if they continue to produce only LDT2 and medium duty vehicles.

2.4 Multi-Manufacturer Ownership Arrangements

In recent years there have been many new multi-manufacturer arrangements, which have made it difficult to delineate individual companies. For example:

- Ford fully owns Volvo and Jaguar, and partially owns Mazda
- General Motors fully owns Saab, and partially owns Suzuki and Subaru
- DaimlerChrysler partially owns Mitsubishi and Hyundai
- Nissan is fully owned by Renault
- Volkswagen fully owns Rolls Royce
- Kia is partially owned by Hyundai, Ford, and Mazda

Thus the question arises—against what base should the “10 percent of sales” ZEV obligation be assessed? Currently, manufacturer sales numbers are not aggregated if the manufacturers are “operationally independent”. Because the meaning of this term is not always readily apparent given the variety of ownership situations, ARB staff held a workshop on March 30, 2000 to clarify the ZEV-related emission compliance liabilities of companies in multi-manufacturer arrangements. Manufacturers have reviewed the implications of using the CAP2000 aggregation provisions for this purpose. (The CAP2000 regulations govern how sales from small manufacturers partially owned by other firms are aggregated for purposes of regulatory compliance).

In general, the CAP2000 provisions are believed by manufacturers to be too restrictive. Manufacturers have recommended alternative procedures, but no consensus exists. Staff will work to finalize a proposal such that majority interest in a company triggers liability for ZEV obligations. The resulting policy will be implemented either by regulatory amendments or through issuance of a

Manufacturer's Advisory Correspondence. Appropriate lead time will be provided before any changes become effective.

2.5 ZEV Production to Date by Large Manufacturers

The ZEVs that have been placed in California by large manufacturers as of March 31, 2000 are described in the following table.

Manufacturer	Model	Battery Type	Lease Cost ($)[a]	City Range[b]	Highway Range[b]	Number Placed
Daimler Chrysler	EPIC	PbA	NA	70	65	17
	EPIC	NiMH	450	92	97	185
Ford	Ranger	PbA	varied	84	69	52
	Ranger	NiMH	varied	94	86	356
GM	EV1	PbA (Delco)	349	75	78	400
	EV1	PbA (Panasonic)	424	111	113	0
	EV1	NiMH	499	143	152	162
	S-10	PbA	439	46	43	110
	S-10	NiMH	440	92	99	117
Honda	EV Plus	NiMH	455	125	105	276
Nissan	Altra	LiIon	599	120	107	81
Toyota	RAV4	NiMH	457	142	116	486

a. Lease prices shown include governmental incentives.

b. Unless otherwise noted, all range figures used in this document are based on the urban dynamometer driving schedule (UDDS) and the highway fuel economy driving schedule (HFEDS) test cycles. Real world driving range will be less.

Overall, manufacturers have adopted similar strategies to make these vehicles attractive to customers. The vehicles typically are available via a three-year lease without a down payment. This reduces the risk to the customer that their vehicle will be obsolete in a few years due to technical advances. Similarly, the warranty provided on the vehicles is comprehensive, and covers all components. This eliminates any durability issues or concerns on the part of the customer. Several manufacturers also include a charger in the lease. Finally, the lease typically includes roadside assistance services.

Because production levels for these vehicles are not yet sufficient to justify assembly line tooling and manufacturing techniques, in many (but not all) cases the vehicles have been produced in a "batch" process. Under this method, a small quantity of vehicles is built at one time. A new batch is produced when necessary.

Some details regarding the specific activities of each manufacturer are provided in the EV Market section below.

2.6 ZEV Volume Estimates for 2003

California sales of passenger cars plus light duty trucks by the large automobile manufacturers total approximately one million vehicles per year. As a rule of thumb, therefore, each one percent of vehicle sales equals about ten thousand vehicles per year.

The calculation of the actual number of vehicles needed to meet the ZEV requirement in any given year is considerably more complex, however, due to several factors:

- Manufacturers can earn "multipliers" for vehicles with extended range, with additional allowances for vehicles delivered prior to 2003. Taken together these two factors can result in up to 10 allowances per vehicle for vehicles delivered in MY 1999 and 2000. Specifically, each ZEV and full ZEV allowance vehicle that is produced and delivered for sale in California in the 1999 to 2007 model years, and that has an extended electric range, qualifies for a ZEV multiplier as shown below. These multipliers are based on range alone and are not dependent on the type of battery or the battery specific energy.

All-electric range	MY 1999-2000	MY 2001 -2002	MY 2003-2005	MY 2006-2007
100-175 miles	6-10	4-6	2-4	1-2

- In addition to the multipliers discussed above, ZEV credits "banked" in a prior year have greater value when "cashed" in a subsequent year, based on the relative values for the NMOG fleet average for the years in question. Under this provision, for example, ZEV credits earned in 1999 are multiplied by 1.82 if used in 2003, and credits earned in 2000, 2001 and 2002 are multiplied by 1.18, 1.13, and 1.1 respectively. Taking into account all available multipliers, a single 175 mile range vehicle placed in 1999 would earn 18.2 allowances.
- Manufacturers are given one additional model year to make up any shortfall in ZEV production. Thus, a manufacturer could choose to satisfy both its 2003 and 2004 obligation with vehicles delivered in 2004.
- In order to meet their obligation, large manufacturers must offer for sale a minimum of 4 percent pure ZEVs. They may, however, choose to meet the entire 10 percent requirement using pure ZEVs.

To provide a context for the Board's evaluation of the ZEV program, staff have developed a "base case" estimate of the number of ZEVs that the large manufacturers must produce in 2003 in order to satisfy the 4 percent ZEV requirement. Due to trade secret considerations this estimate does not rely on any confidential information provided in the manufacturer product plans. Instead, it is calculated using publicly available information, with the following assumptions:

- The vehicles offered for sale in 2003 are identical in performance to the vehicles currently or most recently offered by the manufacturers. (The specific vehicles, their test cycle range, and the resulting number of allowances earned per vehicle are shown below.)
- Manufacturers do not take advantage of the multipliers available for early introduction; the entire 2003 obligation is met with vehicles produced in 2003.
- Each manufacturer's production volume in 2003 is equal to its production volume in 1998.
- Manufacturers meet 60 percent of their ZEV obligation using partial ZEV allowances, and 40 percent of their obligation (4 percent of sales) using pure ZEVs. (An estimate assuming that manufacturers meet their entire 10 percent obligation with pure ZEVs, using no partial ZEV allowances, is shown for comparison purposes.)

With these assumptions, 2003 pure ZEV production would be as follows:

Manufacturer	1998 Production	ZEV model	Urban Range[a]	Multiplier per vehicle	2003 ZEV Obligation	
	(PC+LDT1)		(miles)		4%	10%
GM[b]	84,106	1999 NiMH EV1	143	3.144	1,070	2,675
	84,106	1999 PbA EV1	111	2.293	1,467	3,667
	42,053	1999 NiMH S10	92	1.000	1,682	4,205
TOYOTA	201,473	1998 RAV4 EV	143	3.141	2,565	6,414
FORD	186,977	1999 NiMH Ranger	71	1.000	7,479	18,698
HONDA	172,768	EV Plus	125	2.672	2,586	6,466
NISSAN	88,455	2000 Altra	129	2.773	1,276	3,189
DAIMLER CHRYSLER	105,691	1999 NiMH EPIC	92	1.000	4,228	10,569
TOTAL	965,630				22,353	55,884

a. Test cycle range. Real world driving range will be less.

b. This estimate assumes that GM sales are 40 percent NiMH EV1, 40 percent Panasonic PbA EV1, and 20 percent NiMH S10.

This estimate, at roughly 22,000 vehicles, corresponds to about 2.3 percent of the passenger car and light duty truck production of the affected manufacturers. It must be noted, however, that actual 2003 ZEV production may vary significantly from this number due to the various factors discussed above. For example, several manufacturers have testified that due to lead time considerations they will not be able to take full advantage of the PZEV option in 2003. Thus they will need to place more than 4 percent ZEVs in the early years. On the other hand, the manufacturers' obligations for 2003 can be significantly reduced if they take advantage of the multiple credits available for early introduction. For example, the table below shows the number of vehicles needed by Honda and Toyota to meet the 4 percent requirement in 2003, with and without early introduction of vehicles. Additional credits will be needed to meet the obligation for 2004 and later years.

Scenario	2001	2002	2003	Total (3 years)
Honda, without early introduction	0	0	2586	2586
Honda, with early introduction	500	500	641	1641
Difference	500	500	-1945	-945
Toyota, without early introduction	0	0	2565	2565
Toyota, with early introduction	500	500	742	1742
Difference	500	500	-1823	-823

Looking at the cumulative effect of the program over time, the regulation requires placements in 2004 and 2005 equivalent to those in 2003, and a greater number in 2006 and beyond as multiple credits begin to be phased out. Again using our base case assumptions, the required number of vehicles in 2006 is about 31,000 for a 4 percent requirement, and about 78,000 to meet 10 percent. Thus over the 4 year period from 2003 through 2006, the base case estimate of the total number of vehicles ranges between about 100,000 (4 percent) and 250,000 (10 percent).

Manufacturers are required, under the Memoranda of Agreement with the ARB, to submit confidential product plans outlining the product mix that they will use to meet the 2003 requirement (see Section 3.2.3 below). All manufacturers submitted these plans on a timely basis. All manufacturers demonstrated that they have the technical capability to produce the quantity of vehicles needed to meet their 2003 obligation. The manufacturers uniformly argue, however, that the cost of these vehicles remains high, and foreseeable battery technology will result in limitations on vehicle range. Thus in their view it will be very difficult to develop a self-sustaining mass market for battery electric vehicles at this time.

Staff notes that technical advances are steadily reducing the cost premium associated with ZEVs and that increased production volume will bring about further reductions. Battery cost will, however, remain high for the foreseeable future.

3 COMPLIANCE WITH THE MEMORANDA OF AGREEMENT

3.1 Introduction

In 1996, the Executive Officer of the Air Resources Board and all seven large auto manufacturers signed Memoranda of Agreement (MOAs). The large auto manufacturers who signed the MOAs are General Motors, Ford, Chrysler (now DaimlerChrysler), Honda, Nissan, Toyota, and Mazda. The MOAs are intended to help ensure progress towards a successful launch of a sustainable market for zero emission vehicles in California, by using market based strategies for introduction of zero emission vehicles. They include binding commitments from each of the seven auto manufacturers as well as from ARB.

Under the MOAs, the auto manufacturers committed to:

- Offset the emission benefits lost due to the elimination of the ZEV requirement for 1998 through 2002;
- Establish and maintain the capacity to produce a specific number of ZEVs based on manufacturer estimates of customer demand. Each manufacturer confidentially submitted this information to ARB. Several manufacturers judged the market to be zero, based on available product, planned battery use and anticipated costs.
- Submit annual progress reports, and biennial product plans outlining how they will comply with the 2003 requirement;
- Participate in a technology development partnership, including continued investment in ZEV and battery research and development, and placement of advanced battery-powered ZEVs in marketplace demonstration programs;
- Collaborate with the ARB and the State Fire Marshal on ZEV safety training; and
- Provide the ARB with an on-site review of manufacturer activities and hardware related to the ZEV program.

The ARB, meanwhile, committed in the MOAs to working with state and local governments and others to help develop ZEV infrastructure and remove barriers to ZEV introduction. Specifically, the ARB must:

- Facilitate the purchase of ZEVs in state fleets;
- Address insurance and financing issues;
- Work with other state agencies to ensure the availability of battery recycling;
- Work with local governments on planning and permitting of charging stations;
- Work with utilities and electrical contractor trade groups to ensure adequate training for installation and maintenance of EV charging systems;
- Support the efforts of the National Electric Vehicle Infrastructure Working Council;
- Work with the State Fire Marshal and other emergency response officials to create a comprehensive ZEV emergency response training program;
- Observe the activities of the U.S. Advanced Battery Consortium; and

- Support the development and implementation of reasonable incentive programs that enhance the near-term marketability of ZEVs.

3.2 Manufacturer Commitments

All of the large auto manufacturers submitted the annual reports and the product plans as required. These reports outline the progress made towards meeting the requirements of the MOAs. The following information is based on the manufacturers' submittals as well as private meetings and phone conversations with manufacturers.

Staff concludes that the manufacturers and the ARB have met the commitments made in the MOAs. The remainder of this chapter provides detail on the individual tasks.

3.2.1 Cleaner Cars Nationwide (National Low-Emission Vehicle Program)

The MOAs require the auto manufacturers to introduce low-emission vehicles nationwide in 2001, three years earlier than could be required under federal law. The National Low Emission Vehicle (NLEV) program was included in the MOAs to offset the emission increases associated with the 1996 revisions to the ZEV program, and thereby maintain the integrity of ARB's State Implementation Plan. Because non-California vehicles frequently travel through California or relocate to California from other states, cleaning up non-California vehicles results in emission reductions within California's borders. A 1996 ARB staff analysis indicates that the NLEV program will full meet the 2010 emission goals of the MOA.

In March 1998, the U.S. Environmental Protection Agency (EPA) announced that 23 automobile manufacturers--including the seven manufacturers that signed the MOA--and nine northeastern states have agreed to the new voluntary NLEV program. Starting in 1999, light-duty vehicles and light-duty trucks sold in the northeast are meeting more stringent emission requirements. The program will be expanded nationally in 2001. This agreement between the EPA and the auto manufacturers will fulfill the MOA obligation.

3.2.2 Market-Based ZEV Launch

The MOAs express the auto manufacturers' commitment to have the capacity to produce a certain number of ZEVs "that could be sold in California if warranted by customer demand" (Section I.B.). These vehicles are in addition to the demonstration vehicles discussed under Section 3.2.4.2 below. The specific number was separately and confidentially determined by each manufacturer. The purpose of this element of the MOA was to ensure that manufacturers have the production capacity to meet their estimate of market demand for ZEVs during the ramp-up period prior to 2003. Attached to each MOA as Exhibit A was the manufacturer's confidential November 1995 submittal identifying the manufacturer's annual capacity to produce ZEVs for the 1996 through 2002 model years, in accordance with their estimate of market readiness. Several manufacturers judged the market to be zero, based on available product, planned battery use and anticipated costs.

The timing of vehicle introduction by the various manufacturers has varied, based upon the type of vehicle, the battery employed, specific technical challenges that needed to be overcome, and near-term targeted markets. As of January 2000, Ford, General Motors, Honda and Toyota have placed a total of 738 vehicles above and beyond those required under the MOA demonstration program.

The RAV 4, Altra and EPIC vehicles are currently only marketed to fleets, and production quantities are limited. Honda has announced that it will not produce additional vehicles, and will focus its efforts on evaluating customer satisfaction and providing customer support for vehicles currently in service. The net result of these manufacturer actions is that fleet customers face limited product availability, and the only vehicle marketed to retail customers, the EV1, is sold out. There is no four passenger, family vehicle currently available to the public.

Some parties have argued that the limited availability of vehicles constitutes evidence that manufacturers are not complying with their MOA commitment. As defined in the MOA, *"Capacity to produce" means that the manufacturer has available adequate vehicle production facilities either in-house or contractually with others, including the in-house ability or outside contracts sufficient to supply major vehicle parts and component needs. "Capacity to produce" does not obligate the manufacturer to produce, deliver or sell a specified number of ZEVs.* (Definitions, Section X.D.). A lack of available product therefore does not in and of itself signify noncompliance with the MOA.

An evaluation of compliance with the market-based ZEV launch requirement of the MOAs also requires an interpretation of the phrase "if warranted by customer demand". In the view of staff, a reasonable interpretation of customer demand implies demand that exists when the vehicle is priced at or near the manufacturer's cost. The current lease rates for the vehicles do not recover the relatively high cost of producing an EV today. Although it is common for manufacturers to sell some vehicles at a loss for larger corporate strategy purposes, the current differential between the lease prices for battery electric vehicles and the manufacturers' cost is substantial. Manufacturers have used various methods to determine the lease prices used for today's vehicles, but in no case have the vehicles been priced at a level that is close to the manufacturers' cost. Although we do not know what demand would exist if the vehicles were priced to recover at least the majority of their cost, presumably it would be less than that seen over the past several years.

In sum, staff concludes that manufacturers are in compliance with their commitment to have the capacity to produce vehicles that could be sold in California if warranted by customer demand. As is discussed in the EV Market chapter below, however, the production gap between now and 2003 is interfering with the necessary continuity in ZEV market penetration.

3.2.3 Zero Emission Vehicle Product Plans

Under the MOAs, the manufacturers are required to submit ZEV product plans prior to November 1 of the year preceding the scheduled review (in this instance, prior to November 1, 1999). Each manufacturer must submit corporate product plans that demonstrate compliance with the ZEV requirement for 2003. All of the manufacturers submitted the required plans on a timely basis. The product plans identify the manufacturers' strategies for 2003, including key decision points and other milestones.

ARB staff have carefully reviewed the product plan submittals. Staff also made site visits to Japan and Michigan to tour the manufacturers' research and development facilities, and receive briefings on their research efforts. Based upon the review and site visits, staff is confident that the product plans accurately represent the status of work at the manufacturers.

The information in these confidential product plans provides part of the basis for the staff assessment of the current status of ZEV technology, discussed elsewhere in this document.

3.2.4 Technology Development Partnership

Under the Technology Development Partnership component of the MOA, the auto manufacturers agreed to make good faith efforts to promote and develop a market for ZEVs and to ensure ongoing ZEV-related research and development. To accomplish this effort, each manufacturer committed to continue battery research and development throughout the term of the MOA, and to place new ZEVs with advanced technology batteries into service in California through the advanced technology battery demonstration project.

3.2.4.1 Research and Development

All of the large manufacturers have extensive internal research and development efforts underway. The briefings and staff site visits in Michigan and Japan conclusively demonstrated that all manufacturers are actively pursuing a full range of zero and near-zero emission vehicle technologies. The extensive staffing levels and other resource commitments dedicated to advanced technology give evidence of the manufacturers' conviction that in the future, customers will be favorable towards products that offer ongoing environmental improvement. Staff was impressed with the intense work underway in a variety of program areas, and the commitment by all manufacturers to play a leadership role in the commercialization of zero and near-zero emission vehicles.

In addition to in-house efforts, under the terms of the MOA General Motors committed to contribute $8.9 million during Phase II of the United States Advanced Battery Consortium (USABC), while DaimlerChrysler and Ford have committed $3.34 and $6.67 million respectively. All three manufacturers are on target with their contributions and will completely contribute the full amounts by 2002.

3.2.4.2 Advanced Technology Battery Demonstration Project

The auto manufacturers each also agreed to produce their pro-rata share of up to 3,750 advanced battery vehicles between 1998 and 2000, and place them in demonstration programs designed to validate the new technology. Table 3-1 below shows each manufacturer's share of the total ZEVs to be placed in demonstration programs.

To receive MOA ZEV credit towards the commitments enumerated in Table 3-1, a ZEV must use advanced batteries. For the purposes of the MOAs, "advanced battery" means a battery with a specific energy of at least 40 watt-hours per kilogram (Wh/kg) for the 1998 calendar year and at least 50 Wh/kg for 1999 and subsequent calendar years. (Specific energy is the amount of energy per unit of weight and is related directly to range).

Table 3-1
Auto Manufacturer MOA Advanced Battery Demonstration Commitments

Calendar Year	Number of Vehicles (Based on Average Market Share)							Total by Year
	Chrysler	Ford	General Motors	Honda	Mazda[a]	Nissan	Toyota	
1998	51	181	182	101	28	70	135	748
1999	103	363	365	202	55	141	271	1,500
2000	103	363	366	203	55	141	271	1,502
Total								3,750

a. Mazda's MOA obligation has been met by Ford.

The amount of credit given in the MOA for an advanced battery-powered ZEV is based on the specific energy of the batteries. Manufacturers may reduce the total number of ZEVs required if the batteries used in the vehicles have a specific energy greater than 50 Wh/kg. Table 3-2 on the next page indicates the number of credits that are granted for ZEVs that use advanced batteries.

Table 3-2 MOA ZEV Credits Allowed for an Advanced Battery-Powered ZEV	
Specific Energy	Number of ZEV credits allowed
40 Wh/kg (1998 only) 50 Wh/kg (1999 and 2000)	One
60 Wh/kg	Two
90 Wh/kg	Three

The advanced battery-powered vehicles that are being produced today have specific energy ratings of between 55 and 85 Wh/kg depending on the battery technology used. It is expected that advanced battery-powered EVs to be marketed in 2003 will fall approximately within this range as well.

Linear interpolation is used to determine the number of MOA credits earned by ZEVs with specific energy over 50 Wh/kg. Therefore, ZEVs placed as part of the Technology Development Partnership are generating from 1.5 to 2.8 MOA ZEV credits per vehicle. As a result, the actual number of vehicles to be produced to meet the auto manufacturers' advanced battery vehicle MOA commitments will be approximately 1,800 rather than 3,750.

In early 1999, both Honda and Toyota completed placement of advanced battery-powered electric vehicles for the Technology Development Partnership. General Motors, Ford, DaimlerChrysler and Mazda are on track to complete their commitments by the end of 2000. Nissan requested and received approval to delay placement of a small portion of their vehicles for one year (until 2001) due to a battery supplier issue.

As of January 2000 there were already more than 1,300 advanced battery electric vehicles placed in California as a result of this project. At the conclusion of the project, there will be more than 1,800 electric vehicles operating on advanced technology batteries on the roads of California.

3.2.5 Annual Reports

The MOAs require manufacturers to file an annual report within 90 days after the close of each calendar year. The annual reports must provide information regarding ZEVs placed in California and elsewhere in the United States during the previous calendar year. The annual report must also contain information regarding the placement of ZEVs under the Technology Development Partnership. All manufacturers have submitted their annual reports as required.

3.2.6 Collaboration with ARB and State Fire Marshal

The MOAs require manufacturers to collaborate with the ARB and the State Fire Marshal to develop the curriculum and materials necessary for a comprehensive ZEV safety-training program. This training program, which was completed in 1998, is described in more detail under the description of ARB's related commitment in Section 3.3.8 below.

3.2.7 On-Site Review

The MOAs require the manufacturer to provide ARB staff with an on-site review of activities and hardware related to the manufacturer's ZEV program. ARB staff visited Honda, Nissan and Toyota facilities in Japan in December 1999, and visited General Motors, Ford and DaimlerChrysler facilities in Michigan in February 2000. During these visits ARB staff received extensive briefings on the manufacturers' activities, and had the opportunity to view and/or test-drive a variety of vehicles. As a result of these visits and the information that has been provided, ARB staff have a thorough understanding of the status of work at each manufacturer.

3.3 Air Resources Board Commitments

As its part of the MOA, ARB committed to a number of tasks aimed at making California ready for the ZEV market. The following sections summarize the activities that the ARB has undertaken or supported to meet the commitments made in the MOA.

3.3.1 Purchase/Lease of EVs by State and Local Governments

The MOAs specify that ARB must facilitate the purchase of ZEVs for appropriate applications in state fleets. ARB must work with the California Department of General Services and the California Energy Commission to establish vehicle specifications for the State Bid List, and work with the Department of General Services Office of Fleet Administration to ensure the sale or lease of ZEVs to selected state agencies.

The Department of General Services has executed Master Service Agreements with the General Motors Acceptance Corporation (for the EV1 and the Chevrolet S-10), American Honda Motor Co., Inc. (for the EV PLUS), Toyota Motor Company (for the RAV4), and Ford Motor Credit (for the Ford Ranger). These Master Service Agreements allow all state agencies, as well as the University of California, California State University, the Community Colleges, and local governments, to lease ZEVs according to pre-defined and pre-approved terms, conditions and lease rates. This greatly simplifies the leasing process and allows for more rapid acquisition of vehicles. Additional Master Service Agreement with DaimlerChrysler Corporation (for the EPIC) and Nissan (for the Altra EV) are currently being developed.

As of May 2000, 28 different state and local agencies have leased or committed to lease more than 100 vehicles under these Master Service Agreements and prior agreements. These numbers are expanding rapidly due to the ***ev Sacramento*** program, discussed in Section 3.3.1.2 below. Leases or commitments have been made by the following:

- Department of General Services
- Department of Water Resources
- Department of Forestry and Fire Protection
- Department of Justice
- Department of Parks and Recreation
- Department of Food and Agriculture
- Department of Toxic Substances Control
- Department of Social Services
- Cal/EPA
- Air Resources Board
- Integrated Waste Management Board
- California Energy Commission
- California Highway Patrol
- CalTrans
- Bureau of Automotive Repair
- Office of State Printing
- Franchise Tax Board
- California Exposition and State Fair
- University of California, Davis
- University of California, Los Angeles
- California State University, Chico
- Sacramento County
- City of Sacramento
- City of Citrus Heights
- Sacramento Metropolitan Air Quality Management District
- Sacramento Metropolitan Airport
- Sacramento Public Library

These totals do not include a large number of local agencies that have leased ZEVs using mechanisms other than the state Master Service Agreement.

The ARB and other state and local agencies have undertaken other activities to further encourage ZEV leasing, such as the following:

3.3.1.1 The EV Loan Program

To encourage the use of EVs in public fleets and address its obligation under the MOAs, the ARB designed a three-year program to loan EVs at no cost to federal, state and local government agencies. The South Coast Air Quality Management

District provides financial support for the operation of the program within its jurisdiction. The Department of General Services (DGS) assists with housing, maintaining and dispatching the loan program EV fleet.

The goals of the EV Loan Program are to encourage EV leasing by providing public agencies with a no-risk opportunity to see if electric vehicles meet agency needs, familiarize senior officials with vehicle capabilities, and publicize the availability of electric vehicles to governmental agencies and to the public at large.

The loan fleet includes fifteen vehicles--four GM EV1 vehicles with lead acid batteries (currently returned to GM due to the recall), six Honda EV Plus vehicles with nickel metal hydride batteries, and five Ford Ranger pickups with nickel metal hydride batteries. Six additional vehicles (two Chevrolet S10 pickups and four Toyota RAV4 vehicles, all with nickel metal hydride batteries) have been ordered to expand the program.

The EV Loan Program began operation on a pilot basis in Sacramento in March 1998, using one Honda EV Plus that was provided by the DGS. The loan program's own vehicles were delivered in June 1998 (EV Plus), August 1998 (EV1), and January 1999 (Ford Ranger). The program expanded to Los Angeles in September 1998, the Bay Area in October 1998, and San Diego in April 1999.

As of June 2000 , there have been more than 131 loans completed. Loan durations ranged from several days to three months, but the majority were one month. Fifteen loans are in progress, and thirteen additional agencies are waiting to participate. Although forty-three vehicles have been leased as a result of the program, this number would be higher if additional vehicles were available.

The EV Loan Program is a large-scale effort to provide public agencies with the opportunity to drive EVs. The program has demonstrated that public agencies, when given real-world experience with EVs, often find that the vehicles provide an environmentally sound way to meet many of their fleet needs. The agencies have been able to develop a good understanding of EV range, reliability, operating and maintenance costs, infrastructure requirements, and other data needed to make informed leasing decisions, both now and in the future.

In response to this program and to show support for EVs, many government agencies and utilities have adopted resolutions that require that EVs be purchased or leased for their fleet. These agencies have the necessary funding available but cannot get the vehicles. Thus the goal of this program--to encourage EV leases--is frustrated when there are no vehicles available.

This program has also provided ARB staff with extensive experience with EVs on longer trips in real world conditions. In order to supply EVs to as many agencies as possible, ARB staff have delivered these vehicles to agencies in areas such

Santa Cruz, Bodega Bay, Sonoma County, Channel Islands National Park, Ventura County, San Jacinto, Lake Perris and Palm Springs. Although additional planning and time is needed to deliver the vehicles to these areas, staff have always been successful and have learned a lot about the functionality of EVs in real world conditions.

3.3.1.2 Department of General Services Outreach

The Department of General Services, Office of Fleet Administration, has an aggressive program in place to encourage state agencies to lease electric vehicles. In addition to its support for the EV loan program described above, the Department:

- Provides free daily use of EVs through the state vehicle pool fleet
- Provides ride and drive opportunities to state executives
- Provides flexible lease terms with no-penalty cancellation provisions
- Sends letters to state fleet managers and Business Services Officers outlining EV availability
- Showcases EVs at numerous conferences and other events
- Participates in the national Clean Cities program
- Maintains a web site providing information on EV options

3.3.1.3 ev Sacramento

Many California public agencies are already using electric vehicles. EVs are being driven by agency administrators, field and technical staff, and have been incorporated into a variety of public programs. One barrier that has hindered public agencies in acquiring electric vehicles, however, has been their higher initial cost when compared to their conventionally fueled counterparts.

ARB is committed to increasing the use of EVs by State agencies, and initiated ***ev Sacramento*** to assist with this commitment. The goal of ***ev Sacramento*** is to assist State and local public agencies in the Sacramento region to lease EVs at competitive prices. By offsetting the initial higher costs of these vehicles, this program will significantly expand the use of EVs in the Sacramento area.

The program is jointly administered by the ARB and the Department of General Services Office of Fleet Administration. ***ev Sacramento*** is a three-year program, and includes most of the EVs that are now commercially available. The vehicles that are available through the program include the GM EV1, Toyota RAV4 EV, Ford Ranger, , and the Honda EV Plus. Program staff is also working with Nissan to include the Altra in the program. Vehicle rollout began in May 2000. State and local agencies in the Sacramento area are eligible to participate. Participants pay reduced lease payments that are comparable to lease rates for conventional vehicles. In addition, ***ev Sacramento*** staff coordinate the delivery of the vehicles and the installation of charging infrastructure, and provide all training and user support.

As of June 2000, 21 state and local agencies have committed to lease 76 vehicles. ***evSacramento*** is currently fully subscribed, and there is a waiting list of public agencies that would like to lease vehicles if they become available. Originally 120 vehicles were to be included in the program; however due to limited vehicle availability staff has only been able to lease 76 vehicles to date. Although placements to date are less than the target of 120 vehicles, this is solely due to the lack of vehicle availability. The current mix of vehicles in the program is 34 RAV4 EVs, 30 Ford Rangers, 2 EV1s, and 10 Honda EV Pluses. Staff is currently working with Nissan to include ten Altras into the program.

3.3.1.4 State Budget

Each year, the state Budget Act appropriates funds from the Petroleum Violation Escrow Account (PVEA) to support a variety of energy and transportation projects. Portions of this funding have been used to subsidize the purchase of electric vehicles and infrastructure by local agencies.

The 2000-2001 Governor’s Budget includes significant funding from the Petroleum Violation Escrow Account and the General Fund for electric and alternative fuel vehicles, incentives and infrastructure. Highlights include:

- $5 million for the Air Resources Board to participate in the Fuel Cell Partnership
- $6 million for the California Energy Commission to establish a clean fuels infrastructure for public agencies
- $5 million for the California Energy Commission to establish the Vehicle Efficiency Incentive program to provide incentives for the lease or purchase of electric, hybrid electric, and fuel cell vehicles
- $1 million for the California Energy Commission to develop a hydrogen fuel infrastructure as part of the Fuel Cell Partnership
- $0.5 million for the California Energy Commission to study issues affecting hydrogen fueling infrastructure
- $4 million for the Department of General Services to purchase alternative fuel vehicles for the state vehicle fleet

3.3.2 Insurance

The ARB is required to work with the California Department of Insurance to establish reasonable rates for insuring new ZEVs, to promote insurance industry awareness of ZEVs, and to resolve other issues related to insuring ZEVs.

ARB staff and Department of Insurance staff are not aware of any insurance issues that have arisen with the market-based launch of EVs over three years ago. The EV user has had little difficulty obtaining necessary insurance. At least one manufacturer, Honda, includes comprehensive and collision insurance in the lease package. For drivers of other EV models, the insurance experience appears to have been smooth, with comparable coverage and rates available including second car discounts. On occasion, the EV user may need to spend additional time in the process if the insurer has not had experience writing a policy for an EV.

Based on an informal ARB staff survey of retail EV users in California, it appears that insurance for EVs is available from virtually every insurance company licensed to do business in California. Staff also met with a local insurance broker, who represents a larger company, to discuss the process for establishing the insurance rate for an EV. The broker indicated that the process is identical to that used for any vehicle on the market. With the make and model in hand, the broker looks up a vehicle's "insurance rating group" (IRG). Vehicles with similar characteristics, (e.g., replacement and repair costs, typical damage, and model year) may be placed in the same IRG. If a vehicle has not been assigned to an IRG, or is a new model or model year not covered by an IRG, the industry standard practice is to calculate a rate based on the manufacturer's suggested retail price (MSRP). The broker visited by staff had an IRG manual that contained specific instructions for EV rates to be calculated using the MSRP.

As no significant insurance issues have arisen with the market-based launch, ARB staff concludes that insurance issues will not present obstacles to further expansion of the EV market. Staff will, however, continue to monitor insurance availability for EVs as the market grows.

3.3.3 Financing

The ARB is required to work with the California Department of State Banking to develop risk assessment data to assist in securing financing for the purchase or lease of ZEVs.

To date, financing issues have not presented obstacles to further expansion of the EV market. Financing has not presented a problem for retail consumers because to date the vehicles are primarily leased rather than purchased. The decision to lease EVs to consumers rather than sell the vehicles has not been based on concerns about financing availability. Rather, the auto manufacturers have indicated that offering lease programs to consumers protects customers from risks associated with investing in new, quickly changing technology. ARB staff will continue to monitor these areas to ensure that any future issues that arise are dealt with in a timely manner.

3.3.4 Battery Recycling

The MOA directed the ARB to work with the Department of Toxic Substances Control, the Integrated Waste Management Board, and the Office of Environmental Health Hazard Assessment to ensure the availability of sufficient battery recycling capacity.

To address issues related to EV battery disposal and recycling, the ARB contracted with ARCADIS Geraghty & Miller in 1994. This contract work was broken into two main tasks. First, the contractor evaluated battery technologies based on their performance and recyclability. This work was completed in March of 1995. In addition to determining where efforts should be focused in establishing new recycling facilities and developing cleaner technologies, task one recommended that a deposit of between $100 to $150 be levied on light-duty vehicle batteries to ensure they are returned for recycling.

Task two compared the relative health and hazard impacts from EV battery recycling technology, and was completed in April of 1999. The main focus of task two was to compare the relative impact of recycling EV batteries in terms of cancer, toxicity, and ecotoxicological potential, as well as leachability, flammability, and corrosivity hazards. These impacts were evaluated for recycling methods, including smelting, electrowinnowing, and other appropriate techniques that apply to different battery technologies. A multi-attribute impact analysis was performed on the health and hazard effects resulting from the recycling and disposal of each battery type. The methodology used a semi-qualitative ranking to weight the relative impact and establish a health and environmental impact score for each battery type.

Due to the substantial uncertainties surrounding the analyses, the methodology is designed for comparison purposes only. While current battery constituents are fairly well known, they do vary with manufacturer and are likely to change in the future. In addition, there are substantial uncertainties surrounding the health impact values and future recycling technologies. With this said, a broad conclusion of the analysis is that the more advanced batteries represent a great improvement over conventional lead-acid batteries, both in terms of battery performance and impacts from recycling spent batteries.

In addition to this contract work, ARB staff has also followed battery recycling issues at the national level by participating on the Department of Energy's Advanced Battery Readiness Working Committee. One of the Committee's main activities is to address issues related to EV battery disposal and to review progress made in developing new recycling methods for advanced batteries.

At this time, there do not appear to be any overwhelming obstacles to recycling the battery technologies expected in the 2003 timeframe. Currently, there is one facility in the United States capable of recycling nickel-based batteries. Another plant in Canada is now successfully recycling large military lithium-based batteries. While recycling technologies are being developed and are expected to be in place, it will be necessary to build new recycling plants for certain battery types, such as lithium-ion, to accommodate their use in large quantities. Any new recycling facilities would be required to meet stringent air quality and environmental regulations that would minimize any adverse effects of the recycling processes.

3.3.5 Assist Local Governments with Public Infrastructure

The MOA requires the ARB to work with automakers, the California Energy Commission, and local governments to provide assistance in planning and permitting quick charge and public charging stations. ARB has worked with utilities and electric vehicle infrastructure providers to assess charging station implementation issues and ensure that public charging facilities are developed as needed. This group instigated and coordinated the development of training for building officials involved with permitting and inspection of infrastructure installations. Specifically, following adoption of the California code revisions described under Section 3.3.6 below, a training program was developed for building officials that covered the following:

- The new Building Code and Electric Code provisions governing EVs;
- Plan check and inspection techniques for the new regulation;
- An overview of current and emerging EV technologies including automotive, batteries and charging equipment;
- An opportunity to see and drive current production vehicles; and
- Hands-on experience with charging system equipment.

The current status of public infrastructure is discussed in more detail in Section 6.2 below.

3.3.6 Training for Installation and Maintenance of EV Charging Stations

The MOAs directed ARB to work with utilities and trade groups representing electrical contractors to provide training for installation and maintenance of electric vehicle charging systems.

To address issues associated with installation of EV chargers, especially related to building codes, electrical codes and training of permitting and inspection personnel, the California Energy Commission formed the Building Codes Working Group. The Building Codes Working Group included the Energy Commission, the ARB, the California Building Officials, the California Electric Transportation Coalition, California utilities, General Motors, and Hughes Power Systems. The Building Codes Working Group developed revisions to the California Building Standards to allow for safe installation of electric vehicle charging systems. The Building Code changes, effective in 1996, defined EV charging equipment, added safety requirements, clarified the definition of refueling, and added ventilation requirements. The Building Codes Working Group also modified the California Electric Code to include a requirement to use approved or UL listed EV charging equipment.

In an effort to provide a national standard for building code requirements related to EV charging systems, the Building Code Working Group focused much of its efforts through 1997 on preparing modifications to the National Electric Code. Changes suggested by the Building Code Working Group were forwarded to the

National Infrastructure Working Council for approval and submittal to the National Electric Code governing organization.

Additional activities of the Building Code Working Group included development of Interim Disabled Access Guidelines for Electric Vehicle Charging Stations in cooperation with the State Architect. Since EV charging stations are offered as a service to the general public, they are required to be accessible to those with disabilities. The guidelines give potential public infrastructure providers guidance on making installations accessible to those with disabilities.

The final project undertaken by the Building Code Working Group was the development of an informational brochure for building officials, contractors and consumers. The brochure provides information about permitting and inspection requirements, cites appropriate building and electric codes and gives phone numbers for agencies that can provide further information.

Between 1996 and 1997, California electric utilities and infrastructure providers met monthly to establish and coordinate the multiple steps of the charger installation process. Southern California Edison has written and distributed installation guidelines for private electrical contractors and utility personnel. electric utilities have trained their own customer service and operations personnel on EV installations, established 800 numbers for EV-related inquiries, and created special EV rates. Utilities and infrastructure providers continue to provide training for individual jurisdictions on an as-needed basis.

Extensive training for EV charger installations is also conducted by equipment manufacturers and installation service providers. There are now at least two dozen licensed electrical contractors who are certified to do installations. When larger numbers of vehicles become available there will be a need to expand the network of trained installers, but the procedures for ensuring safe code-compliant installations are already in place and residential installations have generally been proceeding smoothly.

3.3.7 Support Efforts of National Infrastructure Working Council

The National Infrastructure Working Council was initiated by EPRI, at the request of its member utilities, to work on a variety of infrastructure issues including standardization of power supply, emergency disconnect, and standard conductive and inductive charging systems. California's electric utilities have played an active role in the Council. Under the MOAs, ARB is required to support the Infrastructure Working Council's efforts.

ARB staff has attended the Infrastructure Working Council's meetings, observing and participating in the Health and Safety Committee, the Connector and Connecting Stations Committee and the Connector Standardization Subcommittee of the Bus and Non-Road Committee. ARB's participation in the Health and Safety Committee has been focused on assistance with the proposed modification of the National Electric Code. ARB and California Energy

Commission staff have observed and provided comments to the Connector and Connecting Stations Committee. This Committee, in turn, provided input to the Society of Automotive Engineers, which adopted a single standard for the butt-type conductive connector used by Honda and Ford. ARB staff has also observed the early work of the Bus and Non-Road Committee and has been asked to participate in the Connector Standardization Subcommittee as it works to determine the need for connector standardization for buses and non-road vehicles.

3.3.8 Training Programs for Emergency Response

ARB is required to work with the State Fire Marshal and other state and local emergency response officials and towing companies to create a comprehensive training program to ensure preparedness for incidents involving EVs.

Similar to the Building Code Working Group, the California Energy Commission formed the Emergency Response Working Group with ARB, the California Office of the State Fire Marshal, the California Highway Patrol, utilities, auto manufacturers and industry organizations such as the California Electric Transportation Coalition. The purpose of the working group was to develop training designed to inform emergency response personnel about EVs and the differences in response procedures for incidents involving EVs.

In 1998, the Emergency Response Working Group completed the development of a training program consisting of material to train instructors, an instructor's manual and compact disc, and slide teaching materials and student manuals. Train-the-trainer courses have been held throughout the state. Through the Infrastructure Working Council, the complete package of training materials has been distributed to every state Fire Marshal Office in the United States.

Some local Councils of Government have taken the initiative to train their member jurisdictions. To staff's knowledge, no public safety issues have arisen regarding the safety of EVs or the actions of emergency response personnel in responding to an EV accident.

3.3.9 Observe Activities of the U.S. Advanced Battery Consortium (USABC)

The MOAs require ARB to maintain its commitment to observe the activities of the United States Advanced Battery Consortium (USABC) regarding the development of advanced technology batteries. The mission of the USABC is to pursue research and development of advanced energy systems capable of providing future generations of electric vehicles with significantly increased range and performance. The USABC has defined Mid-Term, Intermediate-Term ("Commercialization") and Long-Term criteria that set forth increasingly stringent goals for acceptable electric vehicle performance and economics. Now widely accepted as goals for ongoing development, these criteria are viewed by the

USABC as the minimum standards that must be met if EVs are to be acceptable to a significant percentage of vehicle users.

Through the USABC, the three large U.S. vehicle manufacturers are committed to development of advanced batteries in keeping with their MOA obligation. ARB staff continues to attend the USABC Technical Advisory Committee (TAC) meetings on a quarterly basis. By attending these meetings, ARB staff is able to monitor the progress of USABC contracts with various developers and gain insight as to the contractors' progress. While much of the information obtained is confidential, the following provides a general overview of current USABC activities and developments.

The USABC completed its developmental efforts for Mid-Term battery technologies in 1999. The SAFT nickel-metal hydride (NiMH) and Ovonic Battery Company (OBC) NiMH technologies successfully demonstrated improvements in battery performance, cycle life, and cost reduction. For example, compared to the USABC Mid-Term goals of 80 Whr/kg, 150 W/kg, and 1,000 cycle life, both developers have achieved at least 70 Whr/kg, 150 W/kg, and 800 cycles. In fact, the SAFT technology has realized a cycle life well in excess of 1,000 cycles. For hybrid applications, where power is of greater importance than energy, OBC has achieved specific power levels surpassing 750 W/kg. While the cost of each NiMH technology is currently more than twice the USABC Mid-Term goal of $150/Kwhr, both manufacturers have successfully reduced production cost by over 25 percent during the last two years.

Current USABC programs are focused on long-term battery technologies and meeting the USABC Commercialization and Long-Term and goals. Two major contracts are currently in place investigating lithium-based battery technologies. The SAFT Lithium-Ion contract is currently in Phase I of the development process and is primarily focused on cell and module optimization. The Lithium-Polymer contract is also at the development phase with promise to offer a safe and cost effective battery technology within the next five years. These lithium-based technologies are expected to achieve specific energies well in excess of 100 Whr/kg. Improved specific power of greater than 200 W/kg and a cycle life of more than 600 are also expected. The key characteristic of battery cost should also benefit from these two technologies.

The USABC is expected to initiate a Phase III program this year. Phase III funding will be approximately $62 million and span a total of four years. USABC has indicated that those technologies capable of realizing the long-term goals will be considered.

3.3.10 Reasonable Incentives

Under the MOAs, ARB must support the development and implementation of reasonable incentive programs that enhance the near-term marketability of

ZEVs. Because ZEVs are a relatively new technology and are currently produced in limited quantities, they are more expensive than conventional vehicles. To enhance vehicle marketability in the near term and to assist in the transition to large volume production, it is vital to provide support, both monetary and non-monetary, in the form of vehicle and infrastructure incentives.

Where possible, the ARB and other state agencies have supported the development and implementation of various incentive programs. The California Energy Commission has continued to support vehicle buy-down programs at the district level and has recently provided matching funds for the development of EV infrastructure. Recent legislation authored by Assembly Member Cuneen and signed by Governor Davis allows single occupant vehicles with “inherently low emissions” (ZEVs, as well as vehicles using alternative fuels, with extremely low tailpipe emissions and zero evaporative emissions) to use high occupancy vehicle lanes.

The following list provides an example of the federal, state, local and private incentive programs currently available.

3.3.10.1 Federal Incentives

- Tax credit for 10 percent of the cost of an EV, up to $4,000, through 2004.
- Business tax deduction of $100,000 for electric recharging sites.
- The Energy Policy Act of 1992 authorized a ten year $50 million EV demonstration program and a fifteen year $40 million cooperative program between government and industry to research, develop and demonstrate EV infrastructure. (To date no funds have been appropriated for this purpose.)
- Elimination of the luxury tax for alternative-fueled vehicles.

3.3.10.2 State of California Incentives

- Incentives are available to reduce the lease cost of EVs. In general half of the funding is provided by the California Energy Commission, with matching funds from local air quality management districts. The air district programs are described below.
- CEC funds support the installation of EV charging infrastructure by new purchaser or lessee.
- PVEA funds are made available to local governments to support the lease of alternative fuel vehicles.
- Senate Bill 1782 (Thompson, 1997) reduced the vehicle registration fee for EVs by charging EVs an amount corresponding to the fee that would be due for a comparable conventional vehicle.
- As of July 1, 2000, EVs with the appropriate permit sticker are allowed access to HOV lanes regardless of the number of occupants.

3.3.10.3 Local Incentives

- The Mobile Source Reduction Committee (MSRC) of the South Coast Air Quality Management District was the first to offer public and private customers an EV buydown. A $5,000 rebate per EV purchased or leased is available through their Quick Charge EV buy-down program.
- The MSRC, through its ZEV Purpose Built Buy-Down Program, has provided incentives to fleets in the South Coast Air Basin that have purchased or leased a minimum of ten ZEVs. This program has provided incentives for 400 EVs at $5,000 each for the United States Postal Service.
- The MSRC in conjunction with the CEC and auto manufacturers provides incentives for consumers or fleets using the Quick Charge and/or Purpose Built Fleet Buy Down incentives to defray the cost of installing a charger at one's home or worksite.
- The Bay Area Air Quality Management District (BAAQMD) “Charge!” program offers grants to subsidize installation of public EV charging stations. To date $150,000 has been awarded for 26 sites, and additional funds are available.
- The BAAQMD's Vehicle Incentive Program (VIP) provides public agencies with $6,000 per highway ZEV, $3,000 per city ZEV and $1,500 per neighborhood and three-wheeled ZEV.
- In conjunction with the CEC, several Air Pollution Control Districts offer $5,000 for the purchase or lease of EVs for public and private customers.
- The Los Angeles Airport offers free parking and charging for EVs in its Central Terminal Area. Charging stations were installed at the Los Angeles Airports as part of the Quick Charge Los Angeles EV program.
- The City of Sacramento offers free EV parking and charging at city garages.
- The City of San Francisco is installing EV charging at city garages.
- The City of Vacaville provides $6,000 per EV purchased or leased as well as incentives to city fleets and for charging infrastructure.

3.3.10.4 Utility Activities

- The Los Angeles Department of Water and Power, Sacramento Municipal Utility District, Pacific Gas and Electric Company, Southern California Edison, and the San Diego Gas and Electric Company all provide “time of use” rates to retail EV customers. Time of use rates are very low during hours in which demand is low, such as off-peak and overnight when most EVs are being charged. Additional electricity use during these hours can benefit utilities by using existing capacity built to meet peak demand but otherwise lying idle, and by allowing more efficient generation by online power plants. These time of use rates typically result in at least a fifty percent reduction in the cost of charging, with rates around 5 cents per kilowatt-hour.
- The shareholders of San Diego Gas and Electric have provided $50,000 in seed money to help local businesses and governments install charging stations in the utility’s service area.
- To encourage market development, California’s electric utilities have been loaning electric vehicles to their public and private customers since the early

1990’s. While this activity is not part of the MOAs, it indicates active support for the ZEV program.

In addition to the incentives and other activities described above, the ARB has been working cooperatively with government agencies, auto manufacturers and other stakeholders to determine the most effective way to support the introduction of ZEVs into the marketplace.

On problem in the development of the EV market has been the timing of incentive availability versus vehicle availability. The first incentive program, adopted by the MSRC, was in place more than a year before any vehicles were offered for lease. Now, many incentive programs are in operation but there are few vehicles available.

New monetary as well as non-monetary incentives need to be investigated in addition to possible extensions of the incentives that currently exist. Many of these existing incentives were put into place prior to the 1996 amendments to the ZEV program and end prior to 2003. It would be appropriate to extend them through 2003 to foster the commercialization of ZEVs during the market-based introductory period as well as provide incentives for the vehicles at a time when they will be required in larger quantities.

3.4 Additional ARB Activities

ARB has instigated or been involved in a number of outreach programs, events and research contracts in addition to those addressed in the MOAs. Board members and staff have participated in local outreach as well as attended conferences and exhibitions promoting the use of zero-emission vehicles.

3.4.1 ARB Test Fleet

The ARB has acquired a test fleet of EVs, with three GM S-10s, three GM EV1s, and two Honda EV PLUS vehicles. In an effort to gather information about the vehicles, their usage patterns, and issues associated with everyday EV use, ARB has set up a system to allow ARB employees to use the vehicles for between two days and a week. Employees are encouraged to do outreach to schools and other local groups. Participating employees are given a specific vehicle to drive for a week or a weekend and are encouraged to use the vehicle for as much of their normal driving as possible. Employees are then required to fill out a log that indicates usage pattern and any suggestions regarding vehicle usability and accessibility. This system has been very successful and gives ARB and users the opportunity to gain valuable experience with EVs and infrastructure. Based on discussions with employees and entries in the EV logbooks, these experiences are typically very positive and users find that the vehicle meets practically all their driving needs.

ARB staff have also driven a wide range of other vehicles to learn first hand about their operating characteristics.

3.4.2 EV Rental Demonstration Program

The ARB and the South Coast Air Quality Management District (SCAQMD) are working together to support an electric vehicle rental demonstration program. This program will provide high visibility and convenient availability of EVs. The EV Rental Demonstration has the following objectives:

- Establish a successful EV rental program that will give a large number of the general public and government employees the opportunity to experience the benefits and attributes of EVs.
- Provide positive image of EVs for public and policy makers.
- Gain valuable information regarding the use of EVs in rental car fleets.
- Provide clean air benefits in those areas renting the EVs.

EV Rental Cars L.L.C. was chosen through a competitive bidding process to conduct the EV Rental Demonstration program. EV Rental Cars is working jointly with Budget Rent-a-Car to rent EVs. EVs are currently available for rent at the Los Angeles International Airport, the Sacramento International Airport, Ontario International Airport, and Beverly Hills. The program is slated to expand to additional Budget Rent-a-Car locations at Burbank Airport, John Wayne Airport in Orange County, and downtown Sacramento.

The ARB is providing $100,000 to co-fund this program and 5 Honda EV Plus vehicles. The SCAQMD is providing $200,000. In addition, EV Rental Cars and the other subcontractors involved in the program will cost-share by contributing $252,000 in cash and $523,755 in-kind to this project. These subcontractors include SMUD, the City of Burbank, the City of Anaheim, the Los Angeles Department of Water and Power, and Southern California Edison.

3.4.3 EV Long-Term Placement Program

The Honda Motor Company provided funding for Supplemental Emission Projects, as part of a Settlement Decree with ARB. The Supplemental Emission Projects include the Electric Vehicle Long Term Placement Program, under which 25 Honda EV Plus electric vehicles have been made available to public agencies for long-term loans (6 months to one year). The goals of the Electric Vehicle Long Term Placement Program are to promote greater awareness of electric vehicles among the public, familiarize senior public and private officials with electric vehicles and their capabilities, and encourage the leasing of electric vehicles by public agencies.

The Electric Vehicle Long Term Placement Program is a three-year program, now in its first year of operation. Vehicles have been placed with a variety of public agencies:

- Yosemite National Park (2 vehicles)
- State Parks in Sacramento and San Diego (1 vehicle each)
- Griffith Park, Los Angeles
- San Joaquin Valley Air Quality Management District
- Sacramento Metropolitan Air Quality Management District
- Ventura County Air Pollution Control District
- Yolo-Solano Air Pollution Control District
- Resources Agency Secretary
- Trade and Commerce Agency Secretary
- EV Loan Program, Bay Area (2 vehicles) and San Diego (1 vehicle)
- DGS State Garage Daily Rental
- ARB vehicle fleet (4 vehicles)
- EV Rental Fleet (5 vehicles)

Agencies that have received vehicles will provide a brief report at the end of the placement. The report will summarize the accomplishments of the program, identify activities in which the vehicle was used, and note any problems that occurred. This data will provide on-going information by which to evaluate the effectiveness of the program, as well as track any vehicle or charging problems that may have occurred. After agencies have concluded their loans, ARB staff will solicit new participants for the program.

3.4.4 Participation in Conferences and Exhibitions

ARB has participated in a number of conferences and exhibitions including the North American Electric Vehicle Infrastructure Conference, several international Electric Vehicle Symposia, the World Electric Vehicle Expo, the Los Angeles International Auto Show, and various Clean Cities Conferences. ARB has attended, contributed papers and/or purchased booth space at these and other gatherings. In addition, Board members and staff have participated in ride and drive programs, public relations events and technical advisory groups.

3.4.5 Outreach Events

Board members and staff have been very proactive in conducting public outreach to schools, community events, and community groups. These outreach events have been very successful at a "grass-roots" level. Often, a Board or staff member is accompanied by a member of the Zero-Emission Vehicle Implementation Section who may give a presentation or participate in a demonstration of the vehicle.

Over the past twelve months, ARB staff using vehicles from the ARB test fleet have participated in thirty-four outreach events at schools and more than twenty other events at youth groups, fairs, Earth Day celebrations, and other similar locations. Over the same time period staff from the ZEV implementation Section participated in an additional sixteen events including Science Day at the State

Capitol, Clean Air Day, and the Los Angeles International Auto Show. These events provide participants with an opportunity to gain experience with new vehicle technology and have questions answered about EV capabilities.

4 VEHICLE TECHNOLOGY ASSESSMENT

4.1 Introduction

In June 1999, ARB began meeting with auto manufacturers to discuss their obligations and plans for meeting the ZEV requirement in MY 2003. In December 1999 and February 2000, ARB staff visited all the large volume manufacturers in Japan and in the US to examine, first hand, the progress each manufacturer is making in preparing to meet the ZEV requirement as detailed in their product plans. Prior to the site visits, each manufacturer had provided ARB staff with product plans describing in detail how they intend to meet the MY 2003 ZEV requirement. The product plans included information regarding key development stages, decision points, and other milestones. In addition, the site visits provided ARB staff with a chance to examine prototypes of various types of advanced vehicle technologies.

This chapter discusses the development status of “pure” zero emission vehicles, and “full” and “partial” ZEV allowance vehicles. It concludes with a discussion of new categories of vehicles such as city and neighborhood electric vehicles. These latter vehicles are discussed separately because they have different operating characteristics than full range vehicles and are intended to fill different market segments.

4.2 Pure ZEV Vehicles

This section evaluates the progress made to date in developing “pure” zero-emission vehicles--vehicles having no direct emissions. Vehicles can be certified as ZEVs if they produce zero exhaust emissions of any criteria pollutant (or precursor pollutant) under any and all possible operational modes and conditions. These vehicles do, of course, result in a small amount of indirect emissions at stationary sources such as power plants or hydrogen production facilities due to the generation of electricity or hydrogen for use on board the vehicle. In the discussion of vehicle emissions (Section 9) the indirect emissions and environmental impacts from these stationary sources will be quantified in order to allow a meaningful comparison to other vehicle technologies.

Pure zero-emission vehicles hold distinct air quality advantages over technologies that use a conventional fuel such as gasoline in a combustion engine. Vehicles with combustion engines inevitably exhibit deterioration that results in increased emission levels as the vehicle ages. They are also subject to becoming gross polluters if critical emission control systems fail. High volatility liquid fuels such as gasoline are responsible for significant fuel cycle emissions. For all of these reasons, vehicles with no potential to produce emissions are the “gold standard” of even the cleanest, most advanced new technologies.

From the inception of the ZEV program, the battery electric vehicle has been the leading candidate for meeting the ZEV percentage requirements due to its stage of commercial development. Since 1990, worldwide effort in the research and development of vehicle and battery technology has advanced the prospects for the successful commercialization of electric vehicles. More recently, fuel cell technology has gained worldwide attention as a technology capable of supplanting current internal combustion engine vehicles in the market while providing zero direct emissions (when using stored hydrogen). The following sections provide a summary of the developmental status and infrastructure needs for these two technologies.

4.2.1 Battery Electric Vehicles

Battery electric vehicles were first commercialized more than one hundred years ago. After giving way to gasoline vehicles in the first part of this century, several efforts were made in the 1960's and 1970's to reintroduce and commercialize the technology. While the basic concept of today's electric vehicle remains the same, significant advances in components and vehicle technology have provided new opportunities for the use of electric drive in passenger vehicles.

4.2.1.1 Description of Technology

Battery electric vehicles use an electrochemical battery to store energy. In addition to this energy source, an electric vehicle employs an electric powertrain that includes a motor and controller. Electric vehicles use one of three different types of electric motors: DC (both series and shunt), AC-induction, and permanent magnet DC-brushless. Controllers used with these motors are usually either solid-state electronic, pulsed-width modulation with power transistors, or insulated gate bipolar transistors. Other components include the battery management system, battery charger, state-of-charge meter, charging connector, and electronic protection devices.

4.2.1.2 Development Status

Historically, the inability of batteries to store sufficient energy at a reasonable cost has limited the market for battery electric vehicles. However, considerable advances in the last ten years in component technology have greatly improved overall vehicle efficiency and thus range. By improving the efficiency of drivetrain components and optimizing the combined operation of the battery and drive train under normal operating conditions, EVs currently available can deliver nearly three times the range of EVs from the 1970's having the same amount of stored energy. Just as important, these advances have also included new designs that are projected to be cost comparable to the internal combustion engine vehicle in large volume production (not including the battery). At mandate volumes, however, cost studies conclude that electric vehicle drivetrains, not including the battery, will be more expensive than ICE vehicle drivetrains.

The improved efficiency has been achieved in large part due to the improvements in efficiency of each component mentioned above and through the integrated operation of battery and drivetrain under normal vehicle operating conditions.

California's electric utilities have been involved in the technology assessment of EVs for the past 10 years. Utility fleet data provides an excellent means of observing how EVs operate in daily use. Staff has received comments from the California Electric Transportation Coalition as well as workshop presentation from the fleet manager for Southern California Edison. This information indicates that today's EVs have proven reliable. The Southern California Edison EV fleet employs over 8,000 kWh of NiMH batteries that have traveled over 3 million EV miles. Some vehicles are approaching 40,000 miles with no repairs required. The battery module failure rate for the fleet has been less than 0.07 percent.

4.2.2 Fuel Cell Vehicles

Fuel cells are electrochemical devices that allow for the conversion of chemical energy of fuels directly into electricity. By doing so, the technology avoids the loss of efficiency and emissions of air pollutants that occur with the use of combustion-based engines. While originally discovered in 1839, the first practical use of the technology occurred during the early years of the manned space program in the 1960's. Subsequent manned space efforts, up to and including the Space Shuttle program, have continued to rely upon fuel cells for electric power. This success, in turn, has resulted in large efforts and investments in the technology to develop fuel cell technology for both stationary and mobile applications.

More focused efforts to develop the technology for transportation have resulted in significant improvements in the core technology. The key motivations for this recent interest include concern over urban pollution, a need for alternatives to a diminishing oil supply, and growing concern over global climate change due to carbon dioxide emissions from mobile sources. Because fuel cells are powered by alternative fuels, and operate at high efficiency, fuel cell vehicles can help achieve both energy efficiency and energy diversity goals. A fuel cell vehicle can either store hydrogen or obtain hydrogen through the reformation of an alternative fuel.

4.2.2.1 Description of Technology

While there are several different fuel cell technologies available for use in vehicles, the leading candidate for automotive application is the proton exchange membrane (PEM). Simply described, a fuel cell consists of a membrane, two electrodes, and gas chambers. In acid electrolyte, hydrogen reacts at the electrode, giving up electrons while hydrogen ions are passed through the electrolyte. The electrons are used to operate an electric motor that can then propel the vehicle. After transferring to the cathode side, the hydrogen ions combine with oxygen (typically from the air) and the electrons that have produced work, to form water. Since no combustion is involved, water is the only byproduct from the process. Many of the same components needed by a battery electric vehicle (e.g. the electric power train) are also necessary in a fuel cell electric vehicle.

4.2.2.2 Development Status

In 1998, the ARB contracted with a Panel of experts in fuel cell technology to assess the current status of fuel cells for transportation applications. According to the Panel's review of the technology, significant advances in fuel cell stack technology in recent years have overcome the technical barriers to attaining the performance needed for fuel cell electric vehicle engines.

Efforts are now ongoing worldwide to integrate the latest fuel cell designs into fuel cell engines, and ultimately fuel cell electric vehicles. The biggest challenge now facing automakers is to package the necessary hardware and reduce the cost of the technology to a level comparable to the internal combustion engine. Based on recent visits to manufacturer research and development facilities, however, staff concludes that mass production fuel cell vehicles will not be available until beyond 2003.

Manufacturers continue to advance the state of fuel cell technology. For example, recent news reports have described:

- Significant improvement in fuel cell stack performance under freezing conditions
- Development of next generation stacks that provide higher power while reducing system size and weight
- Introduction of new prototype vehicles by DaimlerChrysler, Ford (Th!nk) and General Motors
- Development of advanced fuel system technologies
- Groundbreaking for the headquarters and associated support facilities for the California Fuel Cell Partnership

The availability projection noted above applies to for fuel cell vehicles that reform (or extract hydrogen from) a fuel such as methanol or fuel cell compatible gasoline on board the vehicle. The operation of a reformer, however, results in ozone precursor emissions. Thus, to achieve zero direct emissions the vehicle has to store hydrogen on board the vehicle. While this greatly simplifies the vehicle's design (e.g. no reformer), it raises new issues regarding the storage of sufficient quantities of hydrogen on the vehicle. The storage of hydrogen, even at fairly high compression (e.g. 5,000 psi), requires roughly 10 times the volume that is needed for the storage of an equivalent amount of energy in gasoline form. Because the fuel efficiency of a fuel cell is significantly higher than that of an internal combustion engine, less fuel is needed to go a given distance. Nevertheless, passenger cars are not currently able to accommodate enough hydrogen for adequate range without seriously compromising the passenger and cargo space.

Manufacturers have explored options that include storing the hydrogen in low-temperature liquid form, or bound chemically to a metal alloy. Efforts continue, but the potential for breakthroughs in hydrogen storage remains uncertain. While a hydrogen fuel cell vehicle is believed to be the best long-term approach, its commercial introduction is not expected until beyond 2003. As part of research and development of fuel cell vehicles, automakers will demonstrate passenger cars using stored hydrogen in liquid form. The goal is not to demonstrate the commercial feasibility of this design, but rather to test, evaluate and refine all aspects of the fuel cell stack and engine.

To address fuel cell vehicle and infrastructure issues, in April 1999 California Governor Gray Davis and industry leaders announced a fuel cell vehicle Partnership that will demonstrate clean transportation technology on California's roadways in the future. The "California Fuel Cell Partnership - Driving the Future" makes the state home to a unique collaboration of auto manufacturers (DaimlerChrysler, Ford, Honda, Hyundai, Nissan, Volkswagen), energy providers (BP Amoco [formerly ARCO], Shell, Texaco), fuel cell companies (Ballard Power Systems, International Fuel Cells), and government agencies (California Air Resources Board, California Energy Commission, South Coast Air Quality Management District, United States Department of Energy, United States Department of Transportation). Associate members, who bring specific expertise to aid in fuel, vehicle and bus demonstration activities, include Air Products and Chemicals, Inc., Linde AG, Praxair, Methanex, the Alameda-Contra Costa Transit District, and the SunLine Transit Agency.

The Partnership will demonstrate fuel cell powered electric vehicles under real day-to-day driving conditions. The Partnership will place about 50 fuel cell passenger cars and fuel cell buses on the road between 2000 and 2003.
In April 2000 the Partnership formally signaled the start of construction for a fuel cell vehicle headquarters facility in West Sacramento with a groundbreaking ceremony. The facility, which will house fuel cell electric vehicles and a hydrogen refueling station, will serve as an operations base for executing the Partnership's goals of demonstrating fuel cell vehicle technology and an alternative fuel infrastructure over the next four years. The 55,000 square-foot, state-of-the-art facility is expected to open in autumn 2000.

4.3 Full and Partial ZEV Allowance Vehicles

In 1998 the ARB modified the ZEV requirement to allow ZEV credit to be earned by vehicles with near-zero emissions. This section discusses the development status of such vehicles.

4.3.1 Definitions and Requirements

Under LEV II, ZEV-like vehicles may qualify to earn a ZEV allowance of between 0.2 and 1.0 per vehicle. Vehicles that qualify for a ZEV allowance of 1.0 are known as full ZEV allowance vehicles. Vehicles that qualify for a ZEV allowance of between 0.2 and 1.0 are known as partial ZEV allowance vehicles (PZEVs). Staff believes that this ZEV allowance approach towards satisfying the ZEV requirement will promote the continued development of battery-powered electric and zero-emitting fuel cell vehicles, while encouraging the development of other advanced technology vehicles that have the potential for producing extremely low emissions and some ZEV-like characteristics. Manufacturers will be able to decide which mix of vehicles makes the most technological and economic sense based on their own strengths in each area.

Large automakers must meet at least 40 percent of their ZEV requirement with pure ZEVs, full ZEV allowance vehicles, or credits generated by either of these vehicle types. They may meet the remaining 60 percent of their overall ZEV requirement with PZEVs earning ZEV allowances of less than one.

To earn a ZEV allowance for a vehicle, the manufacturer must, at a minimum, meet the following baseline PZEV requirements:

- Certify vehicle to 150,000 mile SULEV emission standards
- Certify vehicle to zero evaporative emission standards
- Certify vehicle to meet OBD II requirements for SULEVs, and
- Extend performance and defects warranty to 15 years/ 150,000 miles

One important advantage of battery and hydrogen fuel cell electric vehicles is that their “tailpipe” emissions do not increase when their components fail and are in need of repair. The extended warranty requirement for PZEVs is a very important element of LEV II and is intended to address this issue. It requires manufacturers to provide a 150,000 mile emission warranty under which all malfunctions identified by the vehicle’s OBD II system will be repaired under warranty for a period of 15 years or 150,000 miles (whichever occurs first). This warranty is necessary to ensure that vehicles receiving credit for near zero emissions are able to maintain this performance throughout the useful life of the vehicle, as is the case with pure ZEVs.

Vehicles that meet all of these minimum or “baseline” requirements earn a 0.2 PZEV allowance. Since ARB regulations do not specify particular fuel or propulsion technologies, there is a wide variety of potential vehicle fuel and drive system combinations that may qualify for PZEV allowance in the coming years. The overall ZEV allowance assigned to a vehicle is the sum of 3 individual assessments:

- Baseline (minimum) PZEV allowance 0.2
- Zero emission vehicle miles traveled (VMT) allowance or Advanced Componentry 0.0 to 0.6
- Low fuel cycle emissions allowance 0.0 to 0.2

Table 4-1 on the next page lists a number of existing and hypothetical vehicle types, along with estimates of the maximum potential ZEV allowance they might be eligible to earn:

Table 4-1
Examples of Partial ZEV Allowance Vehicles, Full ZEV Allowance Vehicles, and ZEVs

Vehicle Type (Must meet all PZEV requirements)	Primary Energy Source	Secondary Energy Source	Zero Emission Range (miles)	PZEV Baseline Allowance	Zero-Emission VMT Allowance	Low Fuel Cycle Emissions Allowance	Total ZEV Allowance
Gasoline ICE	Gasoline	N/A	0	.2	0	0	.2
Gasoline ICE / HEV	Gasoline	Electricity	0	.2	.1 (components)	0	.3
CNG ICE	CNG	N/A	0	.2	0	.2	.4
LFCE ICE HEV, 0 mile ZE range	CNG, hydrogen	Electricity	0	.2	.1 (components)	.2	.5
Gasoline ICE HEV, 20 mile ZE range	Grid Electricity	Gasoline	20	.2	.3 +.1 (max off-vehicle charging)	.1	.7
Hydrogen ICE	Hydrogen	N/A	0	.2	.3 (0 NMOG)	.2	.7
Methanol Reformer FCV	FC Methanol	Electricity	0	.2	.3 (0 NOx)	.2	.7
Gasoline ICE HEV, 40 mile ZE range	Grid Electricity	Gasoline	40	.2	.4 + .1 (max off-vehicle charging)	.16	.8
LFCE ICE HEV, 20 mile ZE range	Grid Electricity	CNG, etc.	20	.2	.3+.1 (max off-vehicle charging)	.2	.8
LFCE ICE HEV, 40 mile ZE range	Grid Electricity	CNG, etc.	40	.2	.4 + .1 (max off-vehicle charging)	.2	.9
Direct Methanol FCV	FC Methanol	Electricity	Any				ZEV
Battery EV	Grid Electricity		Any				ZEV
Stored Hydrogen FCV	Hydrogen		Any				ZEV

Abbreviations used in the table are:

CNG:	Compressed natural gas
FCV :	Fuel cell vehicle
HEV:	Hybrid electric vehicle
ICE:	Internal combustion engine
LFCE:	Low fuel cycle emissions
FC Methanol	Methanol that is compatible for use in fuel cells
PZEV	Partial Zero Emission Vehicle
SULEV	Super Ultra Low Emission Vehicle
VMT:	Vehicle miles traveled
ZE Range:	Zero-emission range

It should be emphasized that the LEV II regulations do not establish specific ZEV allowances to be earned with particular fuel or propulsion technology choices. Rather, allowances are earned according to the three factors noted above, and depend on the actual performance achieved by a vehicle with a particular fuel and propulsion technology. The examples in the table below indicate staff's current assessment of the maximum achievable allowances possible for the vehicle types shown.

4.3.2 PZEV Availability

The following section outlines current information regarding the availability of production PZEVs, today and in the future (2003 and beyond).

4.3.2.1 MY 2000 PZEVs Presently Available

At the present time, only the Nissan Sentra 'CA' ("Clean Air") has achieved California certification for PZEV credit. Staff does not anticipate any further applications for PZEV certification for MY 2000 vehicles.

Nissan Sentra CA (Gasoline SULEV, PZEV Credit =.2)

Make	Model	Emissions Class	City/ Hwy EPA MPG	Primary Energy	Secondary Energy	Primary Propulsion	Secondary Propulsion
Nissan	CA	PZEV-.2 (SULEV)	26/ 33	Gasoline	N/A	Gasoline ICE	N/A

The 2000 model year Nissan Sentra CA is the first vehicle to be ARB-certified to meet SULEV requirements as well as the additional warranty and evaporative emissions controls necessary to achieve a baseline PZEV rating. Several key technologies allow the Sentra CA to achieve PZEV performance levels. These include:

- Double-wall exhaust manifolds,
- Quicker warm-up catalyst

- A new combustion control sensor, and
- An electronically controlled swirl control valve that reduces hydrocarbon emissions in both cold and warm start situations.

In addition, the radiators of all Sentra CAs are coated with Engelhard Corp.'s PremAir® coating, which converts ozone passing the radiator into oxygen.

The Sentra CA will be a limited production vehicle. Sales of the Sentra CA began in April 2000 in California.

4.3.2.2 MY 2000 SULEVs Not Qualifying For PZEV Credit

In addition to the Nissan Sentra CA, three other MY 2000 vehicles have met certification requirements for the SULEV standard. These vehicles will not earn PZEV allowances, however, because they do not yet meet all of the minimum baseline requirements necessary for PZEV status.

The MY 2000 Honda Accord SE has been certified to SULEV emissions standards, but has not been certified to attain PZEV allowance requirements for durability, warranty, or zero evaporative emissions at this time. The Accord SE would be eligible for a 0.2 ZEV allowance if the additional PZEV requirements were to be met.

The MY 2000 Honda Civic GX is a CNG fueled ICE vehicle that is ARB certified as a SULEV and already meets zero evaporation requirements. It does not yet offer the enhanced 150,000-mile emissions warranty required for PZEV baseline certification. Honda states that they do not yet have sufficient durability data on this vehicle to justify the warranty extension necessary for PZEV certification. Since CNG fueled SULEVs that qualify for a PZEV baseline allowance of 0.2 would also be eligible to receive 0.2 allowance for low fuel cycle emissions, the Civic GX could someday qualify for a 0.4 PZEV allowance.

The Toyota Prius, the Japanese version of which was the first modern-day HEV to be offered for sale, has been certified as a MY 2001 SULEV. Toyota is not expected to apply for certification to PZEV levels. As of January 2000, Toyota had delivered more than 30,000 units to customers in Japan, and US deliveries are expected to commence shortly.

Although the current Prius HEV is capable of traveling very short distances in ZEV mode, it cannot attain the minimum 20-mile all electric range necessary to earn a zero-emission range allowance. (Note that all energy in the Prius battery is provided by the on-board auxiliary power unit or by regeneration--it does not use any grid electricity). If future versions of the Prius or similar gasoline HEVs with negligible zero emissions range met PZEV requirements, they would attain an overall PZEV allowance of 0.2 baseline plus 0.1 for advanced electric drivetrain componentry, for a total PZEV allowance of 0.3.

Make	Model	Emissions Class	City/ Hwy EPA MPG	Primary Energy	Secondary Energy	Primary Propulsion	Secondary Propulsion
Honda	Accord SE	SULEV	23/30	Gasoline	N/A	Gasoline ICE	N/A
Honda	Civic GX	SULEV	28/34 (equivalent)	CNG	N/A	CNG ICE	N/A
Toyota	Prius	SULEV	52/45	Gasoline	Electricity: 1.8 kWh total energy, ~.18 kWh useful energy[a]	Gasoline ICE, (52 kW)	Electric Motor, (33 kW)

a. In operation the vehicle management system limits battery output to only a portion of its rated capacity.

4.3.2.3 Other Production Vehicles With Some PZEV Characteristics

The Honda Insight is the first modern-day HEV to be offered to customers in California. It is currently certified at ULEV emissions level, so it cannot yet qualify for a PZEV baseline allowance. The Insight HEV design emphasis is on high efficiency, and hybridization enables it to achieve the highest mileage and consequently the lowest CO_2 emissions of any gasoline-powered passenger car available in the United States.

The Toyota Prius platform, if modified to have a larger battery, a larger electric motor, and a charging port, could serve as the basis for a vehicle with significant zero-emissions range. Because the present design of the Honda Insight powerplant links the electric motor directly to the engine, it is not capable of any motor-only, zero-emission operation.

Ford has recently announced that it will be offering a 2003 MY hybrid version of its new sport utility vehicle (SUV), the Escape. This hybrid SUV is expected to achieve nearly 40 mpg (city) and will also be certified to the SULEV emission standard. The hybrid Escape is expected to provide acceleration similar to the V6 Escape, while achieving better fuel economy than the 2 liter 4 cylinder Escape (23/28 mpg city/hwy). Ford is also pursuing the development of a zero evaporative emissions system for the Escape. An Escape that met PZEV requirements would qualify for a 0.3 PZEV allowance.

Make	Model	Emissions Class	City/ Hwy EPA MPG	Primary Energy	Secondary Energy	Primary Propulsion	Secondary Propulsion
Honda	Insight	ULEV	61/70	Gasoline	Electricity ~.9 kWh total, ~.09 kWh useful energy[a]	Gasoline ICE (54 kW)	Electric (10 kW)
Ford	Escape	SULEV (Target)	TBD	Gasoline	Electricity TBD	Gasoline ICE (TBD)	Electric (TBD)

a. In operation the vehicle management system limits battery output to only a portion of its rated capacity.

4.3.2.4 Other Power-Assist HEVs

Staff expects several additional "power-assist" parallel HEVs to become available before 2004. These HEVs are also expected to be equipped with relatively small motors with less than 25 percent of engine power capability, and small battery packs (less than 2 kWh). Although these power-assist HEVs are designed primarily to improve fuel economy and do not necessarily reduce criteria emissions, they can significantly reduce CO_2 emissions. Sales of "power assist" HEVs would also require manufacturers to increase their design and production capability for electric motors, inverters, and battery packs, which may be used in other types of electric-propulsion vehicles.

4.3.2.5 PZEV Availability in MY 2003 and Beyond

Under the ZEV regulation, intermediate manufacturers may meet their entire ZEV obligation using PZEVs, and large manufacturers may meet 60 percent of their ZEV obligation with PZEVs. In order to take full advantage of this flexibility using 0.2 credit PZEVs, intermediate manufacturers would need to certify 50 percent of their fleet as PZEVs (50 percent of the fleet at 0.2 credits per vehicle equals 10 percent) and large manufacturers would need to certify 30 percent of their fleet (30 percent of the fleet at .2 credits per vehicle equals 6 percent). Other than the Nissan Sentra CA, discussed above, no manufacturer has announced definitive plans to market PZEVs in MY 2003. The timing of PZEV introduction likely will be affected by manufacturer-specific external cycles such as the planned retirement date for engine families and their replacement by new engines. Staff anticipates, however, that additional PZEV models will be announced prior to 2003.

Manufacturers have indicated that the most difficult challenges to be met for PZEV certification are the zero evaporative emission level and the 150,000-mile emissions warranty. In public comments, Honda pointed out that it has requested information from ARB regarding specific test procedures to be used to demonstrate compliance with the zero evaporative emission requirement. Staff notes that due to the many variables involved, ARB seeks to provide maximum flexibility and has encouraged manufacturers to develop and propose test procedures appropriate to their individual systems. To date one manufacturer has successfully done so, and it is staff's understanding that other proposals are planned. GM stated in workshop testimony that due to the technical challenges, and the high volume of PZEVs it would need to produce to meet 60 percent of its ZEV requirement (roughly 65,000 vehicles at 0.2 credits per vehicle), GM will be unable to use PZEVs to meet any significant portion of its ZEV requirement in 2003. Another concern stated by GM is the potential impact on the palladium (Pd) market when introducing significant numbers of PZEVs. PZEVs would likely require very high Pd loading on catalytic converters, and with large-scale introduction of PZEVs, GM is concerned that Pd demand will exceed supply, thereby significantly increasing the price of Pd. Staff is unable to verify the likelihood of this scenario.

Other large manufacturers (including Ford, DaimlerChrysler, and Toyota) have indicated that PZEVs will not be available in sufficient quantity to take full advantage of the 60 percent level allowed under the regulation for 2003.

Some intermediate volume manufacturers have also noted specific concerns in meeting the ZEV requirement in the early years (i.e. before 2006). Instead of making limited lines of specialty high ZEV allowance vehicles, as may be an option for a larger manufacturer, an intermediate volume manufacturer will need to incorporate significant numbers of PZEVs into its major product lines in order to meet its ZEV requirement. Such a large-scale introduction will require a longer phase-in period. Therefore, although intermediate volume manufacturers may begin introducing PZEVs in 2003, they have stated that the volume of PZEVs that they are able to produce would not be sufficient to meet the ZEV requirement in the first year of the program. They anticipate reaching compliance within 2 to 3 years. One manufacturer has suggested that manufacturers in such situation may require an extension in meeting the ZEV requirement.

4.3.3 All Electric Range and Efficiency Improvement

Both battery EVs and hybrid electric vehicles with zero-emission range that are able to charge from the electric grid can achieve high efficiency along with extremely low emissions. Today's typical battery EVs achieve efficiencies of 400-500 Whr per mile (AC) and the EV1 efficiency has been tested at 250 Whr per mile. These vehicles thus are demonstrating a plug to wheels efficiency equivalency of 77-154 MPG (assuming energy content of gasoline is 38.6 kWh/gal). This high energy efficiency results in correspondingly low CO_2 emissions. Vehicle CO_2 emissions are discussed more completely in Section 9 below. Although vehicle operating efficiency and CO_2 emissions are not regulated by the ARB, staff recognizes that inefficient vehicles require more costly and complex systems to control criteria emissions. In addition, a malfunctioning low-efficiency gasoline vehicle operating up to 2 years between smog inspections has the potential to emit many times more emissions than a faulty high-efficiency vehicle.

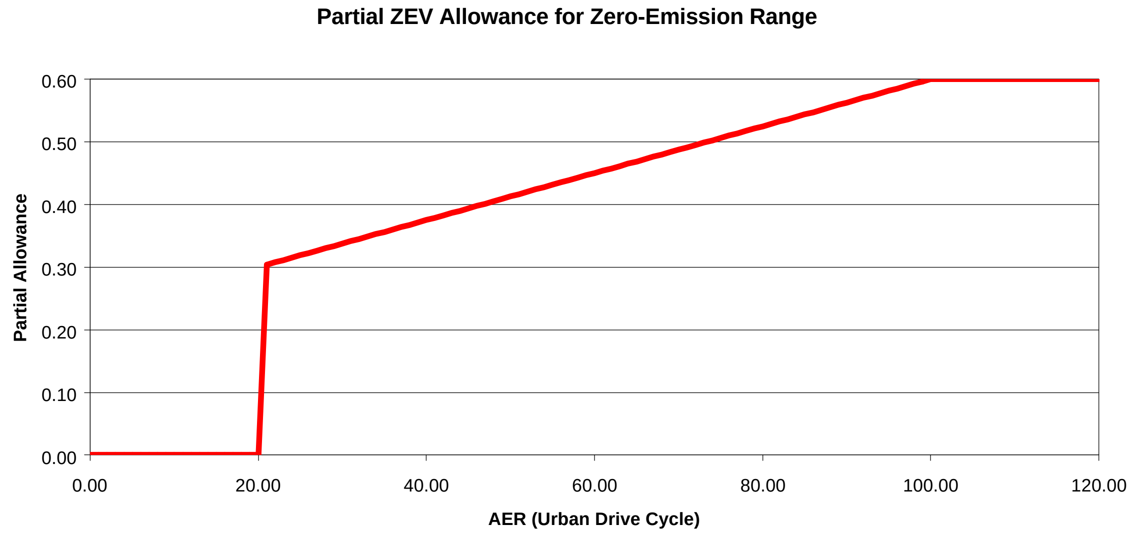
4.3.4 Partnership for a New Generation of Vehicles

The Partnership for a New Generation of Vehicles (PNGV) is a collaboration between the United States Government and the large domestic automakers. The long–term goal of the PNGV is to develop vehicles that will deliver up to three times today's fuel efficiency (80 miles per gallon) and cost no more to own and operate than today's comparable vehicles. At the same time, this new generation of vehicles should maintain the size, utility and performance standards of today's vehicles.

The PNGV program near-term development emphasis has been on diesel-powered vehicles, because its goals are narrowly focused on fuel efficiency. The Partnership has, however, also funded developments that may have significant impact on future emissions reductions. Program contractors have developed improvements in lightweight materials, high-power batteries, fuel cell components, and reductions in vehicle road-load. For example, a recent PNGV-funded prototype announcement for the GM Precept discloses an extremely low aerodynamic drag coefficient of .163, which is less than one-half of the drag exhibited by a typical modern car. The ability of auto manufacturers to reduce aerodynamic drag to these extraordinarily low values will substantially reduce the power and energy storage requirements of future ZEVs and PZEVs, and may accelerate the introduction of cost-effective near-zero or zero emission vehicles.

4.3.4 HEVs With Significant Zero Emission Range

Three PZEV allowances are added together to determine a vehicle's overall allowance. One of these three, the zero-emission VMT allowance, is based on the potential for realizing zero-emission vehicle miles traveled, and is determined as shown in the graph below.



During the development of LEV II, ARB staff believed that manufacturers would develop HEVs with battery packs that were smaller and less expensive than those needed for battery EVs, but still big enough to provide significant ZEV range and to justify recharging from the electric grid. These smaller packs for HEVs might have an energy storage capacity as low as 10-15 kWh instead of 30+ kWh in battery EVs, but would be sufficient to enable vehicles to attain a relatively large zero emission VMT allowance. Based on public announcements to date, however, staff does not believe that grid-charged hybrid electric capability will be made available on any MY 2000-2003 vehicles. The only hybrid electric vehicles expected during this time will probably be equipped with very small battery packs of less than 2 kWh capacity that are charged from gasoline-derived energy only. While LEV II was written to encourage vehicles with zero-emissions range like grid-connected HEVs because of their low emissions, high efficiency, and other ZEV-like attributes, it is unlikely that manufacturers will make use of this option to achieve higher PZEV allowances for zero-emission range before 2004.

Automotive manufacturers and researchers have, however, developed and demonstrated several prototype HEVs that demonstrate significant zero-emission range and are able to charge their battery packs with grid-supplied electricity. No manufacturer has announced when these types of HEVs will become available, and most cite the same primary obstacle that has resulted in the slow introduction of battery EVs--high battery cost. Although many of these advanced prototypes would not yet meet ARB's SULEV requirements, with further engine refinement to SULEV standards they would achieve very high PZEV credits because of their ZEV range capability.

Examples of functional concept "grid connected" hybrid vehicles include:

- Several GM EV-1 based show cars,
- GM Triax,

- DOE/ SAE Futurecar and Futuretruck Student-competition HEVs,
- Suzuki EV Sport,
- Volvo HEV,
- Ovonic-Modified (grid connected) Toyota Prius,
- Audi Duo.

Studies of the feasibility of such vehicles are underway, including work at U.C. Davis and EPRI. Staff believes that such vehicles offer many potential advantages, which justify their favorable treatment under the ZEV credit mechanism. Cost remains an obstacle due to the larger battery packs required for significant all-electric range.

4.4 On-Road Low Speed and City Electric Vehicles

Several classes of small on-road electric vehicles have begun to emerge in the last few years that will displace gasoline vehicle usage and increase overall zero-emission miles traveled within California. These vehicle types include low speed vehicles (LSVs).and city electric vehicles (CEVs). LSVs are not necessarily electric; LSVs that use electric drive are also referred to as neighborhood electric vehicles (NEVs). In this staff report we use “LSV”--the legal classification adopted by the National Highway Traffic Safety Administration—to refer only to electric drive vehicles. The specific characteristics of these vehicle types are discussed in more detail below.

LSVs and CEVs are under consideration because they offer a number of desirable characteristics:

- Very high efficiency
- Affordable to build, and affordable to purchase
- LSV performance is adequate with existing, affordable, lead acid batteries
- CEV battery pack energy storage requirements are only about 1/3 that of a full sized EV, so the latest battery technology can be more affordable.
- Reduced congestion (possible to park two LSVs in a single parking space)
- Many potential niche market applications (station cars, resorts, theme parks, national parks, campuses, planned communities).

4.4.1 Background--Emerging Small EV Classes

Small EVs exhibit a wide range of capabilities and performance levels. They may be broadly classified as shown on the next page. Similar characteristics for full-range EVs are shown for comparison purposes.

Under current state law and ARB regulation, LSVs and City EVs all qualify as “passenger cars” and therefore are eligible to earn full ZEV allowances. In terms of trip replacement and the resulting air quality impact, however, it is clear that a LSV, City EV, and a full-range EV differ significantly. ARB staff plan to better quantify the relative air quality benefits of the various new categories of vehicles.

Vehicle Type	DOT Class	Curb Weight	Energy Storage Capacity	Drive System Peak Power	Maximum Speed	Typical Range[a]	Examples
e-bikes, scooters, motorcycles, etc. [b]	N/A	Varies	0.3- 2.8 kWh	~1kW- ~10 kW	Varies	less than 20 miles	ZAP, ebike, etc.
LSV	LSV (Low Speed Vehicle)	950-1400 lbs.	4-9 kWh	~5-15 kW	Less than 25 mph (limited by LSV rqmnts.)	20-30 miles	GEM, Th!nk Neighbor, Bombardier NV, etc.
City EV (CEV)	PC	1800-2500 lbs. typ.	10-15 kWh	~20-30 kW	Typ. less than 62 mph	Typ. 40-80 miles	Toyota e-Com, Nissan HyperMini, Th!nk City, etc
3-Wheeled Enclosed Motorcycle[b]		Varies	3-10 kWh	Varies	28-60 mph	20+ miles	Sparrow
Full-range EV	PC	3200+ lbs.	15-35+ kWh	50-150 kW	70-80 mph	40-140 miles	EV1, EV-Plus, RAV4 EV, Altra, etc.

a. Test cycle range. Real world driving range will be less.
b. Not eligible for ZEV credit.

4.4.2 City EVs (CEVs)

This emerging class of vehicles is much smaller than most American vehicles and exhibits lower performance than the ICE vehicles currently available on the American market, but they are much more car-like than LSVs. Although the current prototypes listed below are not yet safety certified, production City EVs sold in the United States in quantities greater than 2,000 will be required to meet all existing federal DOT/Federal Motor Vehicle Safety Standards (FMVSS) requirements for equipment and crash protection. All are equipped with dual air bags, and many offer anti-lock braking systems.

Examples of near-term CEVs include:

Make	Model	Passengers	Curb Weight	Maximum Speed	Range[a]/ Power	Battery Type
Toyota	e-Com	2	1742 lbs.	62 mph	60 miles 19 kW	Panasonic NiMH 288 volts x 28 ahr
Th!nk	City (MY 00)	2	2046 lbs.	54 mph	50 mi 27 kW	Saft NiCad 114 X volts 100 ahr
Th!nk	City (MY 01+)	2	TBD	TBD	TBD	TBD
Nissan	Hyper-mini	2	1852 lbs.	62 mph	60 miles 24 kW	Shin Kobe LiIon
Honda	City-Pal	2	2310 lbs.	68 mph	80 miles	NiMH 288 volts 28 ahr

a. Test cycle range. Real world driving range will be less.

Auto manufacturers are planning to sell large quantities of CEVs elsewhere in the world, especially in countries where fuel prices are relatively high or gasoline infrastructure is scarce. Most City EVs fit within the Japanese “microcar” classification limits, which restrict vehicle size to a length of less than 3400 mm (11 feet 2 inches) and a width of less than 1480 mm (4 feet 10 inches). In Japan, there is growing interest in this “microcar” class of for use as second vehicles. Some City EVs whose lengths are less than 2500 mm (8 feet 2 inches) are capable of parking 2-to-a-parking space to help avoid urban congestion. In countries where fuel costs are high, CEVs will be able to provide lower cost of ownership even in the relatively low build quantities expected in the early years of production. They are equipped with battery packs that are approximately one third the capacity (and cost) of those found in full-size, full-performance EVs. City EVs are also expected to demonstrate better operating efficiency than larger EVs and LSVs. All CEVs currently proposed are planning to make use of advanced battery technology (NiMH or LiIon).

Toyota is providing a fleet of 13 left-hand drive eComs for a demonstration program in Irvine, California. This program will be run by UC Irvine’s National Fuel Cell Research Center in cooperation with Toyota. The e-Com can charge at either 120 VAC Level I or Level II Inductive charging stations.

The Th!nk City is currently available for lease in Scandinavia. Plans are for 700 units to be imported into the US in 2000, with more than 300 of them coming to California for demonstration programs. Safety features include a driver-side airbag and seat belts with pre-tensioners.

Nissan’s Hypermini is the only City EV that is presently equipped with Lithium Ion batteries. Safety features include both dual airbags and anti-lock brakes. A Nissan Hypermini station car demo program in Yokohama began in January 2000, with others to follow. Thirty vehicles are allocated for demonstration in California beginning this year.

4.4.3 Low Speed Vehicles (LSVs)

Low speed vehicles have a curb weight of under 1800 lbs., are equipped with speed limiting devices that limit maximum speed to 25 mph, and are restricted to use on roads with posted speed limits of under 35 mph. This vehicle class was legalized on a community basis in California with the passage of Assembly Bill 110 in 1999. Arizona was the first state to legalize LSVs on a statewide basis. LSVs are not necessarily electric drive. In practice we expect that the vast majority of LSVs in California will be electric drive, and in this document we use the term LSV to refer to electric drive vehicles. An LSV with electric drive is also referred to as a Neighborhood Electric Vehicle.

The National Highway Traffic Safety Administration (NHTSA) has excluded LSVs from the category of “passenger car” and defined a new Federal Low-Speed Vehicle class to establish minimum safety and equipment standards for these vehicles (49 CFR Parts 531.3 and 571.500). These regulations define a LSV as “a 4-wheeled vehicle, other than a truck, whose speed attainable in 1.6 km (1 mile) is more than 32 kph (20 mph) and not more than 40 kph (25 mph) on a paved level surface”. Federal requirements do not require LSVs to make use of electric propulsion. The California vehicle code was modified under Senate Bill 186 to accommodate this new federal classification, and these vehicles have been legal for use on public roads statewide since January 2000. Under California law and ARB regulation, however, LSVs qualify as “passenger cars”, even though they are subject to different crash test requirements. Thus federal and state law differ on this point. Because they qualify as passenger cars under state law, LSVs are eligible to earn full ZEV allowances. Another important distinction between Federal and California law is California’s additional restriction of unladen weight to 1,800 lbs. or less.

Although these vehicles appear to be similar to golf carts, they offer substantially more performance, better safety features, and are much more road worthy. LSVs are generally capable of much better acceleration than golf carts and can achieve 25 mph quite rapidly. Golf cart performance is restricted in accordance to cooperative industry standards to 13-15 mph, due to safety and turf maintenance concerns on golf courses. LSVs are usually equipped with higher-pressure road tires that might damage turf if used on a golf course, and LSVs must also be equipped with much better brakes than would be needed on a golf course. At the present time, all LSVs on the market are purpose-built designs intended for use as LSVs and are not derivatives of existing golf-cart designs. These improvements also increase the price of a LSV to more than $3,000, which is more than a typical electric golf cart.

At the present time, LSVs do not display efficiency labeling, as is required of all other road vehicles. Present EPA test procedures specify that the test vehicles must operate at speeds that are above the capability of LSVs, so the existing test procedure cannot be used to measure the fuel economy or range of these vehicles. Although test information is not yet available for these vehicles, it is believed that their operating efficiency may not be nearly as high as that of City EVs, which are equipped with much more technologically sophisticated componentry. In many cases, it is possible that LSV operating efficiency may even be poorer than that of full-size and full-range battery EVs. These vehicles generally have battery pack capacities of about 8 kWh, but the pack cost is quite low due to the low cost of the batteries used.

Examples of near-term LSVs are as follows:

Make	Model	Passengers	Curb Weight	Range[a]/ Power	Battery Type
Th!nk	Neighbor	2	950 lbs.	25 mile/ 5 kW	TBD
Th!nk	Neighbor	4	1200 lbs.	25 mile/ 5 kW	TBD
Bombardier	NV	2		30 mile/ 3.7 kW	Sealed lead-acid 72 volt system
GEM	E 825	2+ short bed pickup	980	25-30 miles/ 2.6 kW	Flooded Lead-Acid 72 volt system
GEM	E 825	2+ long bed pickup	1200	25-30 miles/ 2.6 kW	Flooded Lead-Acid 72 volt system
GEM	E 825-2	2	980	25-30 miles/ 2.6 kW	Flooded Lead-Acid 72 volt system
GEM	E 825-4	4	1280	25-30 miles/ 2.6 kW	Flooded Lead-Acid 72 volt system

a. Test cycle range. Real world driving range will be less.

Deliveries of the Th!nk Neighbor are scheduled to commence in November, 2000. It will be available for sale at selected Ford dealers, via the internet, and at other unspecified outlets, and base price is expected to be approximately $6,000.

Bombardier was the first LSV to apply for ARB certification. The Bombardier vehicles make use of sealed, maintenance-free lead acid batteries, and are available at a base price of $6,199.

GEM has received certification for its MY 1999 vehicles. Prices vary with model, and range from $7,000 to $10,000. Unlike some other LSV models, the GEM charging circuitry is designed to be compatible with existing, 120 VAC commercial GFCI-equipped outlets.

GEM LSVs are the only ones equipped with flooded lead-acid batteries (all others are sealed designs), and will therefore require battery maintenance. GEM recommends checking/ adding battery water to each cell at least once a month.

As noted above, although LSVs are not “passenger cars” under federal law, under current state law and ARB regulation LSVs qualify as “passenger cars” and therefore are eligible to earn full ZEV allowances. Due to their limited range and functionality, it is apparent that such vehicles will replace far fewer vehicle miles traveled, or trips, than City EVs or full range EVs. Staff thus has significant concerns regarding how such vehicles should be treated for ZEV credit purposes. ARB staff plan to evaluate the use and resulting emission benefits of such vehicles as information becomes available.

5 BATTERY TECHNOLOGY ASSESSMENT

5.1 The Battery Panel

The cost of batteries, both today and when produced in volume, is one of the most critical parameters of this review. To obtain the best available assessment, the ARB has contracted with a team of outside experts. The Year 2000 Battery Technology Advisory Panel has met with leading battery suppliers and auto manufacturers. Their task was to review the state of the art regarding advanced battery design and manufacturing techniques, and report back to staff regarding likely cost trends for 2003 and beyond. The Executive Summary of the Panel's draft final report is attached to this Staff Report as Appendix A. The full text of the Panel's report is available on the ARB Biennial Review website at http://www.arb.ca.gov/msprog/zevprog/2000review/2000review.htm.

Interested parties have been given the opportunity to comment on the draft final report. Comments received to date have been conveyed to the Panel for their consideration. The final report will be available to the public at the September 7, 2000 Board hearing and will reflect the comments and feedback received as appropriate.

5.2 Range vs. Cost

The current structure of the ARB regulatory and incentive scheme for ZEVs and partial ZEVs is intended to encourage the development of advanced batteries that will allow battery EVs to achieve extended range, long battery life, and lower lifecycle cost. For example, additional credit is given in the near term for ZEVs with a range of greater than 100 miles.

This approach has been taken in order to encourage the development of vehicles with sufficient range to cover the majority of trips taken by typical drivers. Such range has been thought to be necessary to achieve mass-market penetration. In addition, the use of advanced batteries has the potential to extend the life of the battery pack compared to conventional lead acid batteries, and thereby reduce the need to replace battery packs during the vehicle life. It has long been assumed that technical advances will reduce the cost of advanced batteries such that in addition to providing extended range, they will be more cost effective than conventional batteries on a lifecycle cost basis.

Some parties have argued that the ARB preference for advanced batteries should be revisited. Proponents of this view make the case that lead acid batteries may be cost-effective in several EV and HEV configurations, and they question whether the increased range afforded by advanced batteries justifies the extra cost. They also note that lead acid batteries are well suited for fast charging. Others have argued that one appropriate niche for battery EVs could be smaller, shorter-range vehicles for urban and commuter use, and that the ARB incentive structure should not discourage such applications.

Two threads of public comment that relate to this issue were presented at the March workshop. First, many EV drivers of lead acid vehicles testified that their existing vehicles provide more than adequate range for their daily driving needs. (This point is discussed in more detail in Section 7, of this report, EV Market.) They see no advantage to batteries that provide additional range at an increased cost, and would not take advantage of such an opportunity.

Second, one speaker presented an analysis of the "cost of increased range". In this analysis, the cost of an advanced lead acid vehicle was compared to that of a nickel metal hydride vehicle with greater range. This speaker concluded by recommending that the ARB eliminate the 100-mile minimum electric range threshold for granting multiple ZEV credits. This would allow shorter-range vehicles to qualify for multiple credits, and in the view of the speaker would increase the options available to ZEV manufacturers and purchasers. One possible outcome of this scenario would be a shift towards shorter-range, less expensive lead acid vehicles.

One other effect of such a change would be that larger NiMH vehicles (GM S-10, Ford Ranger, and DaimlerChrysler EPIC), which under the current regulation only get a 1.0 credit because their electric range is less than 100 miles, would get multiple credits. Specifically, if the ZEV multiple credit line were to be linearly extended below 100 miles, in 2003 the S-10 and the EPIC would get about 1.8 credits, while the Ranger would get about 1.2 credits. Thus, without a shift to lower-range lead acid vehicles, fewer vehicles would be necessary to comply with the 2003 requirement.

The staff cost analysis, presented in Section 8, contains a detailed comparison of lifecycle costs for lead acid and NiMH batteries in a variety of vehicle configurations.

5.3 Possible Actions to Reduce Battery Cost

In public comment, several parties suggested that battery cost could be reduced if there were greater standardization in several key areas, including:

- The size and shape of different types of battery packs (NiMH, LiIon, PbA) so that battery packs could be readily switched out without changes to the vehicle.
- Voltage levels among the various manufacturers of NiMH and among the three battery chemistries.
- Battery management systems, both thermal and electrical management.

It also was suggested that guaranteeing a high volume of battery orders to one or more manufacturers could decrease battery cost. Battery manufacturers have indicated that a volume of approximately 20,000 batteries is necessary to realize economies of scale in battery production. Several utilities have proposed a competition among battery manufacturers that would reward the winning company or companies with a large order in return for passing on the cost saving from higher volume production.

6 INFRASTRUCTURE ASSESSMENT

6.1 Introduction

To achieve zero and near-zero (SULEV) emission levels, together with minimal upstream refueling emissions, the advanced technology vehicles being developed by manufacturers often require the use of fuels other than conventional gasoline. Therefore it will be critical to ensure that the necessary refueling infrastructure is in place to support their widespread introduction.

Recently, the South Coast Air Quality Management District and CALSTART announced an Internet web sit that allows drivers of alternative fuel vehicles to locate refueling stations quickly and easily throughout California. The site covers electric, compressed and liquefied natural gas, propane and methanol fueling facilities. The site will also list ethanol and hydrogen fueling facilities when they become publicly available in California. Clean Car Maps is located at http://www.cleancarmaps.com. Users pick an alternative fuel and enter an address and they will receive a map with icons designating the locations of refueling sites in the area. Users can then click on the site name to get comprehensive refueling information from a web database.

6.2 Battery EVs

Public infrastructure enhances the utility of battery electric vehicles. Drivers can extend the length of their trips if they know that convenient recharging facilities will be available at their destination.

The charging facilities at individual locations vary. A grocery location may be equipped with a single electric charging station. A public parking garage is more likely to provide both inductive and conductive charging stations. Major destinations will have a larger number of charging stations. For example, parking Lot 1 at Los Angles International Airport is equipped with ten inductive electric chargers and 6 conductive chargers, and Lot 6 is equipped with additional inductive and conductive electric charging stations.

The public infrastructure for electric vehicle charging continues to expand in California. Currently, there are about 400 public charging stations statewide, which offer about 700 chargers--about 400 inductive and about 300 conductive. The bulk of the locations are in the greater Los Angeles/South Coast area, the San Francisco Bay area, the Sacramento Metropolitan area, and San Diego. In recent years, public infrastructure has expanded to locations in the North Coast, Central Coast, Sacramento Valley and San Joaquin Valley.

Public comments from the California Electric Transportation Coalition provide useful background on EV infrastructure. Points made in the Coalition comments include the following:

- Charging has been successfully deployed for large, centrally fueled fleets. Southern California Edison, for example, has 400 installed chargers with an additional 200 circuits already in place.
- Workplace charging requires more attention. While some employers have been slow to embrace employee charging, others have taken laudable initiatives. Apple Computers in Cupertino will offer their employees free EV charging and parking until 25 percent of the vehicles that employees drive to the Apple site are electric.
- There are still two competing charging technologies, with a single charging standard no closer. Both charger types have proven convenient to use and reliable. Because of the vehicles available, conductive chargers dominate fleet applications, while inductive chargers are more evenly divided between fleet and consumer applications,.
- Prices have come down for both inductive and conductive charging equipment over the past two years, although some chargers are still subsidized by their manufacturers and automakers. Innovations currently being implemented may help reduce equipment and installation costs further. For example, the United State Postal service \fleet will test a conductive dual-head conductive charger that requires no manual intervention to switch from charging one vehicle to another. Use of this type of charger allows for a lower installation cost. Other innovations such as multiple chargers on a single pedestal, or load management systems, will reduce the cost of infrastructure installation per vehicle even further. In addition, one manufacturer has developed a Level 2+ conductive charger that could provide faster charging at a minimal incremental cost.
- Failure rates for chargers have been lower than expected, averaging less than 2 percent where data are available. To date most repairs have been covered under warranty, although with some chargers now coming out of their 3-year warranty period that will change.
- Fast charging has been successfully demonstrated. Chrysler's EPIC minivan is successfully using fast charging for airport shuttle vehicles, demonstrating economic feasibility in a centrally fueled fleet. Fast charging will become more economic as the number of EVs on the road increases.

In public comments, manufacturers noted the extensive efforts by some automakers to develop EV infrastructure. Many of these efforts in the areas of building code revisions, inspector training, and similar preparatory work are discussed in more detail in Section 3 above. Manufacturers also noted that the installed base of public electric vehicle chargers is sparse relative to the installed base of gasoline pumps, especially when the long recharge time needed for electric vehicles is taken into account.

ARB staff will continue participating in efforts to expand public infrastructure for electric vehicles. There do not appear to be any barriers that would prevent the expansion of public charging as needed to accommodate increasing numbers of

EVs on the road. ARB staff has, however, identified several areas that warrant review in the near term:

- Centralization and maintenance of up-to-date information on public charging station locations and operational status, with dissemination of the information via Internet and annual publication (currently being provided by CalStart and Clean Car Maps).
- Review and revision, if appropriate, of the criteria for selecting public charging locations to take into account recent increases in electric vehicle range.
- Modification of the public infrastructure to accommodate upgrades to chargers and connectors, and additional electric charging technologies.
- Development of state regulations and local ordinances to discourage parking of internal combustion engine vehicles ("ICEing") at electric vehicle charging stations.
- Promotion of a courtesy charging protocol to allow more than one user access to a single electric charging station.

One issue of concern that can affect both the cost and utility of public charging is the lack of progress towards a single electric vehicle charging standard. This could increase the cost for installing or retrofitting existing public charging stations if a decision for a uniform standard is not made well before the public charging system is expanded to accommodate increasing numbers of vehicles on the road.

ARB has previously considered the possibility of establishing standards that would govern the type of charger to be installed when public agencies provide incentives or funding for public infrastructure. Staff believes that ARB has the regulatory authority to establish standards for electric vehicle charging systems. It was suggested at the workshop that ARB consider the establishment of a Technical Advisory Panel to make recommendations to ARB on this issue.

6.3 Grid-Connected Hybrid Vehicles

Grid-connected HEVs are generally expected to make use of the same public and private electric charging infrastructure that is currently being installed for battery EVs. One possible difference between battery EVs and PZEV HEVs would be a potential reduction in the demand for higher-power (Level II) charging stations, due to the fact that such HEVs can run on APU power when their battery packs are depleted. It may even be possible for 20 to 40 mile zero-emission range HEVs to make significant use of Level 1 charging (standard 120 VAC), because the smaller battery packs in these HEVs will be able to accumulate useful charge in reasonable time periods with more commonly available Level 1 outlets.

6.4 Fuel Cell Vehicles

In addition to testing vehicles, the California Fuel Cell Partnership (discussed in section 4.2.2.2 above) will also identify fuel infrastructure issues and prepare the California market for this new technology. Initial demonstration vehicles will run on hydrogen, directly from tanks on board the vehicles. Subsequent demonstration vehicles are likely to run on methanol fuel. Technology for other liquid fuels such as a cleaner form of gasoline will be evaluated. A key goal of the Partnership is to determine the best fuel infrastructure for the market entry of fuel cell vehicles.

The Partnership will be devoting considerable attention to fuel cell fuel infrastructure issues. Staff will monitor the Partnership's efforts in this regard and report on status as appropriate.

6.5 Compressed Natural Gas (CNG) Vehicles

There are currently about 230 CNG vehicle refilling stations in California, of which 104 are available to the public. Most of these are "fast fill" type stations that are capable of refilling CNG vehicles in as little as 2 to 4 minutes.

Although the "fast fill" fuel dispensing infrastructure is relatively sparse, low pressure natural gas is already delivered to most residences in California. Thus manufacturers are working to develop "time fill" devices that would be suitable for home refueling use. These "time fill" devices may take 6-8 hours (overnight) to fill a vehicle, but their availability could make dedicated CNG vehicles a much more viable option for non-fleet users.

7 THE EV MARKET

7.1 Introduction

One key issue, as we look to 2003, is the nature and extent of expected market demand for electric vehicles. Does a market exist for a large number of electric vehicles? Of all the issues associated with the zero emission vehicle regulation, this one appears to generate the greatest divergence of opinion and the most strongly held beliefs. It is also the question for which the least amount of hard data is available.

Several basic points have emerged in the course of staff's investigation, workshop testimony, and subsequent public comment:

- Those companies that actively marketed EVs to retail customers (GM and Honda) made broad-based promotional efforts that attempted to assess the potential retail market for EVs. Other manufacturers used marketing efforts appropriate for the fleet market.
- Customer demand for the vehicles, as evidenced by actual leases, was limited under the circumstances and conditions that prevailed in the initial marketing period, and fell short of manufacturer expectations. For many months the available inventory of vehicles was in excess of customer demand.
- At present, due to the halt in EV production by most manufacturers, the demand for vehicles exceeds the available supply, both for retail customers and for fleets. It is unclear if demand exceeds the level that prevailed during the time that vehicles were available.
- The performance characteristics of today's EVs meet a wide variety of potential applications. Drivers of EVs report using the vehicle more than they expected to, and the EV is nearly always the vehicle of choice for trips within its range.
- The process of leasing an EV, as reported by EV drivers and those who attempted to lease vehicles, has been described as far more difficult than the process of acquiring a conventional vehicle. Although the evidence presented is anecdotal, rather than survey-based, staff believes that taken as a whole this testimony provides persuasive evidence that such difficulties indeed have occurred in real world EV leasing.
- Different parties have come to markedly different conclusions regarding the EV market for 2003.

To further address market related issues, this chapter first discusses EV market demand as evidenced to date. It then discusses the potential market in 2003. Finally, it outlines key elements needed to mount a successful EV marketing effort consistent with the 2003 regulation.

We recognize that considerable time and effort could be spent debating the strengths and weaknesses of the manufacturers' past efforts. The central issue before the Board, however, is what is likely to occur under the very different circumstances of 2003. Thus our focus throughout the Biennial Review process is on looking forward rather than backward.

7.2 EV Market Experience to Date

This section summarizes available information regarding EV marketing experience, drawing upon staff's review of marketing strategies and efforts undertaken to date by manufacturers, the results reported during the MOA placement programs, testimony at the March 2000 and May 2000 workshops, and public comment.

7.2.1 Manufacturer Marketing Strategies and Efforts

In letters dated September 28, 1999, and November 2, 1999, ARB staff requested information on auto manufacturers' marketing activities since the initial ZEV launch. All auto manufacturers responded to the request in a timely manner.

The manufacturers offered a variety of EV platforms to the marketplace. Only General Motors offered more than one platform. The majority of the manufacturers targeted fleet commercial customers to meet their MOA obligations. Two manufacturers, GM and Honda, had retail customers as their primary market targets. Table 7-1 below describes each manufacturer's market target groups and its EV platform. The majority offered their EVs through three-year leases. The leases typically covered batteries, maintenance and road service; some leases included insurance or chargers. The lead acid battery version of the Chevrolet S10 Electric truck and the Ford Ranger were offered for purchase.

Table 7-1
Manufacturers' Market Targets and Vehicle Models

Manufacturer	Primary Market Target and Vehicle Model	
	Retail Customer	Fleet/Commercial Customer
Daimler-Chrysler		EPIC (5 passenger minivan)
Ford		Ranger EV (2 passenger truck)
General Motors	GM EV1 (2 passenger car)	Chevrolet S10 Electric (2 passenger truck)
Honda	EV Plus (4 passenger car)	EV Plus (4 passenger car)
Nissan		Altra (4 passenger minivan)
Toyota		RAV4 (5 passenger sport utility)

The majority of the manufacturers describe the introduction of their production EV models as demonstration programs, with goals that focus on advanced battery evaluation and on market and infrastructure issues important for future growth in the EV market. To retain control over the vehicles for evaluation purposes and to protect the customer from "demonstration" EV technology, manufacturers offered the EVs for lease only in most cases. Several manufacturers mentioned that support of charging infrastructure was a component of their marketing of the EVs. The majority identified the fleet market approach as the most reliable and effective means to assess the operational and durability aspects of EVs. Prime fleet customers were identified as those required to purchase alternative fuel vehicles under the Energy Policy Act (EPACT), including government agencies and electric utilities, and companies wanting to promote an environmentally conscious image. Some manufacturers mentioned that they wanted to avoid "higher risk" factors associated with retail marketing. According to information available to ARB staff, about two thirds of the EVs in California have been placed in fleets and about one third have been placed with retail customers.

Several manufacturers reported EV marketing expenditures, on a per vehicle basis, of up to several orders of magnitude higher than expenditures for similar conventional (non-electric) vehicles. ARB staff and some manufacturers attribute the higher expenditures per vehicle to the limited number of EVs being produced and the cost of the additional educational aspects of marketing to promote a new technology. However, ARB staff also received information that indicates that marketing expenditures for a newly introduced conventional car model can be similar in magnitude in the first or second year of introduction.

In the Preliminary Draft Staff Report, staff stated that manufacturers focused their marketing efforts on small, narrow target audiences. In public comments, Honda has presented information indicating that its promotions and marketing efforts were broad-based, and used many of the same techniques that are used for conventional vehicle promotion and marketing. Similar comments were made with respect to GM's marketing for the EV1. Staff agrees that these promotional efforts were directed at broad market segments, and has revised this section accordingly.

The next sections provide more detail regarding the activities of individual manufacturers.

DaimlerChrysler. DaimlerChrysler's demonstration program has used a single EV model, the five passenger EPIC minivan. EPIC is an acronym for Electric Power Interurban Commuter. The EPIC combines the Dodge Caravan/Plymouth Voyager minivan platform with advanced electric vehicle technology and off-board chargers that provide fast recharging capability. Using the fast charge, the EPIC is capable of more than 300 miles service in a single day.

Staff notes that the EPIC's charging system differs from the standard inductive and conductive systems used by all other vehicles. For a captive fleet with central recharging this is not a problem, and the fast charge capability provides significant benefits. For other applications that need to make use of public charging infrastructure, including retail public customers, the lack of a standard charging interface presents an impediment to more widespread use.

DaimlerChrysler chose the minivan platform for the EPIC because of the popularity of its minivans and because of the minivan's versatility to either carry passengers or to be used as a utility vehicle. The EPIC, with a combination passenger and cargo payload of 925 pounds, has initially been marketed for lease to fleet customers. DaimlerChrysler identified governmental entities, electric utilities and commercial fleets with short-range delivery requirements as primary targets with a particular interest in the U.S. Postal Service.

To meet its MOA commitment, DaimlerChrysler began to place MY 1999 NiMH battery-powered EPICs in the 1998 calendar year. To date, 185 EPICs have been placed in California. Major customers include the Xpress airport shuttle service at Los Angeles International Airport, US Postal Service offices in Harbor City and Huntington Beach, UCLA, military bases, municipalities, and business fleets. EPICs are also placed at dealers where they are used for demonstrations.

DaimlerChrysler has used a target-direct-mail campaign with small incentives (including radios and flashlights), advertisements in regional business journals, literature and the normal government and utility fleet bid process to market the EPIC. Fleet managers have been invited to selected dealers for a test ride and may have been visited by DaimlerChrysler's Alternative Fuel Vehicle Sales and

Marketing representatives. The primary marketing theme has been "Meet the EPIC Electric Minivan - Batteries Included" with emphasis on the EPIC's practicality and zero emissions.

<u>Ford</u>. The Ranger EV truck is the single model used in the Ford demonstration program to date. Based on Ford's best-selling compact truck platform, the Ranger EV has a regular cab and payload capacity of 700 pounds if equipped with lead-acid batteries, or 1,250 pounds with NiMH batteries. Ford first introduced its lead-acid battery-powered version of the Ranger EV pickup truck in 1998. The NiMH version was made available in 1999.

Prior to introducing the Ranger EV, Ford conducted focus groups, marketing clinics and dealer meetings. Ford has targeted fleets for these vehicles because it perceives fleet customers as generally having shorter, more predictable driving patterns than retail customers. However, Ford has marketed the Ranger EV to both fleet and retail customers. Sales and service are through Ford dealers to provide customers with a "mainstream" or "conventional car" experience. To date, 356 Ranger EVs have been placed in California (of a total of 915 nationwide). The California customers are predominately government with some utility, private fleet, and retail customers. Ford appears to have retained about ten percent of these California Ranger EVs for demonstration purposes.

Ford reports that it has 15-20 Ranger EVs scheduled continuously at various events including government fleet events, dealer events, media events and auto shows. Other Ford marketing efforts include joint marketing with utilities, telemarketing, direct mailings, Ford websites, and on-going print ads. Ford's marketing message appears to focus on the Ranger EV having the "Best in Class" design features of a gasoline Ranger and proven advanced EV technology to guarantee it is "Built Ford Tough". According to Ford, its California marketing expenditures per Ranger EV in 1999 were 6.5 times that of a comparable gasoline Ranger.

In August 1999 Ford introduced additional incentives to encourage Ranger EV leasing. A reduced lease rate of $199 per month was put into effect for a Youth Awareness Program, and $7000 vouchers were made available to reduce the lease cost to public and private schools, parks, and zoos. These incentives resulted in an increase in lease rates, up to an annual rate of about 1200 vehicles per year.

Ford has entered into an agreement with the United States Postal Service to provide 500 electric vehicle platforms, based on the Ford Ranger, for use as Postal Service vehicles. Most recently, Ford has announced plans to market the two passenger Th!nk City and Th!nk Neighbor vehicles in the United States—the first vehicles of that type to be offered by a major automobile manufacturer in this country. The Th!nk vehicles will be marketed to the general public. Ford has indicated that it believes a market exists in the United States for these urban commuter cars, and has recently undertaken a television advertising effort featuring the Th!nk City. Various demonstration programs featuring the Th!nk and other similar vehicles are being planned.

General Motors. General Motors offered two EV models in its demonstration program, the 2-passenger GM EV1 with a payload of 440 pounds and the Chevrolet S-10 Electric compact truck with a payload of 950 pounds. General Motors has marketed three versions of the EV1--the 1997 Generation I with lead acid batteries, and the 1999 Generation II with advanced lead acid or with NiMH batteries. The EV1 has been marketed for retail applications, with 768 placed in California. The Chevrolet S-10 Electric, offered with lead-acid or nickel-metal hydride batteries, has been marketed for commercial applications with 227 placed in California, out of more than 450 placed nationwide by the end of 1999. The target customers for the Chevrolet S-10 Electric include electric utilities, government agencies, colleges and universities, theme parks, zoos and airports.

In support of EV technology development and marketing, General Motors began consumer research in 1989. Their market research efforts have included a two and one-half year consumer test fleet drive program beginning in 1994 (the PrEView Drive), an early adopter marketing focus group, an EV1 owner survey, and recent market positioning research. Through customer input from the PrEView Drive, General Motors modified its EV product and determined the attributes of the early adopter target market.

General Motors gave the EV1 a unique General Motors (GM) badge and served retail customers through selected Saturn dealers and an EV specialist team. Currently, 33 Saturn retailers in Los Angeles, Orange County, San Diego, the San Francisco Bay area, Sacramento, Phoenix and Tucson lease and service the EV1.

Due to the recent recall, the MY 1997 Gen I EV1 vehicles are being stored by General Motors until the engineering and validation of a new replacement charge port is completed. Drivers who lost the use of Gen I vehicles are being given the option to transition to a Gen II EV1, or wait until rebuilt Gen I EV1s are available. Staff’s understanding is that demand for Gen II EV1 vehicles exceeds the available supply. General Motors has not committed to additional production at this point.

General Motors marketing efforts have targeted regional market locales and used various media including television, radio, outdoor, newspaper, magazines, Internet site, direct mail, and brochures. The marketing efforts include promotional activity at schools and events, an EV1 test drive road show, and owner club support. Marketing themes have included "Upgrade your drive. The electric car is here.", "You can't hear it coming. But it is.", and "Clean air goes in here. Clean air comes out here."

Honda. Honda originally intended to place roughly 75 percent of its 2-door, 4-passenger EV Plus vehicles with retail consumers through selected dealers. Honda started with four dealers and market areas and expanded later to four additional dealers and market areas. To date, about one-half of the 276 vehicles placed in California have gone to retail consumers. While Honda made a deliberate decision to market the EV Plus to a broad market, the EV Plus retail customer profile was typically that of an "Enviro Leader" or a " Techno Champ." The "Enviro Leader' was described as having a concern for society and ecology, at the vanguard of environmentalism, politically active, and pragmatic, seeking a "mainstream EV." The “Techno Champ” was described as the affluent innovator, with a technology focus, driven to make an "EV statement", believing the EV PLUS is the "best EV made”, and dedicated to the EV.

According to Honda, its MOA demonstration program was intended to introduce the product to the retail market, create public awareness and interest in the EV Plus, and get potential customers into the dealerships and encourage them to experience the EV Plus. Honda indicated that it made an extensive effort to market the EV Plus, and provided dealer support beyond that which is customary for Honda or the industry. To that end, Honda reported that it provided free support and training to the dealers, broadly marketed the EV Plus, encouraged and received extensive media evaluation of the product, supported numerous private and public events, placed prominent ads on a regular basis in many magazines and newspapers, and made direct mail solicitations. Marketing themes included "A car with a cord. Sounds like Honda" and "Zero gallons to the mile."

Honda reported that it helped each potential customer assess the possible utility of the EV Plus by considering is operating characteristic, including its "real world" range of 60 to 80 miles per charge. Honda has an ongoing study of EV customers for customer satisfaction. Additionally, Honda has conducted a study of EV "Intenders" (those who expressed interest but did not lease the vehicle). These studies are described below.

In 1999, Honda completed its MOA commitment and finished placing the last of its Honda EV Plus vehicles. Although Honda does not plan to continue production of the EV Plus at this time, it maintains the capability to resume production. Honda currently is focusing its efforts on EV Plus customer satisfaction issues, which will continue at least until the end of the vehicle leases. In addition, at the conclusion of their initial three-year leases the Honda vehicles are being re-leased, with the original customers being offered the opportunity to re-lease the vehicles at a reduced monthly rate of $299.

Nissan. Nissan's demonstration program is using an all-new Altra EV 4-passenger 4-door minivan with a payload of 820 pounds. The Nissan Altra EV is the first production electric vehicle that is equipped with lithium-ion batteries. Nissan outfitted the first 30 demonstration Altra EVs with data loggers that record

31 different types of information on vehicle performance. Nissan also conducted various customer surveys and interviews to provide basic data for evaluation of vehicle performance, and user perception and experience.

Anticipated individual buyers were identified as wealthy homeowners with a fleet of two or more vehicles. The distance between home, work and the nearest Nissan retailer would be typically 30 miles or less. These customers were also expected to be highly educated couples living in suburbs or fringe towns of major metropolitan centers. Technically savvy early adopters, and those committed to environmentally friendly products were also expected to be early Altra EV buyers. Target fleet customers were expected to be both those required to purchase alternative fuel vehicles under the Energy Policy Act (EPACT) and also those companies wanting to promote an environmentally conscious image.

Initially, 30 demonstration vehicles were split evenly between the retail and fleet markets by the Los Angeles office of Nissan's American research subsidiary, Nissan Research & Development. The individual drivers are Nissan employees using the company vehicle lease program; other Altra EVs have been placed with utilities located in Northern and Southern California. A market-oriented program to place 98 demonstration Altra EVs is to be conducted by Nissan's American sales and marketing headquarters, Nissan North America. To date, 81 vehicles have been placed statewide.

The Altra EV vehicles were made available to demonstration customers directly from Nissan through a comprehensive lease program. A direct lease approach was selected for this program rather than a typical dealership distribution so information would flow directly between customers and the test engineers. To date, the majority of Nissan's marketing activities focus on fleet managers, through participation in key conferences and EV events. Nissan has additionally supported various public awareness/educational events. The marketing theme was "a friendly, high-tech electric vehicle for every day life."

After the initial California placement in 1998, Nissan decided to change to a different lithium-ion battery supplier. Due to efforts in making this change, Nissan did not produce any MY 1999 Altras. The new battery pack was incorporated in MY 2000 and was introduced in California in December 1999. Nissan plans to fulfill its MOA commitment by the end of calendar year 2001.

Mazda. To date, Mazda has purchased credits to meet its MOA obligations and therefore has not offered any ZEVs under the Mazda nameplate.

Toyota. The Toyota demonstration program uses a single EV model, the RAV4 EV. This EV is based on an existing platform, Toyota's 4-door, 5-passenger RAV4 sport utility vehicle. The RAV4 EV has a payload capacity of 827 pounds. Toyota considered several surveys of retail customers and placed prototypes with electric utilities before deciding to focus initial marketing efforts on major electric power utilities and fleet customers. Toyota has placed 486 RAV4 EVs in California to date (of 683 placed nationwide), primarily in electric utilities and government fleets. Toyota initially provided RAV4 EV servicing through contracted utilities and a municipality, and later expanded to offer service at a few select dealers.

To reach the fleet market, Toyota has concentrated RAV4 EV advertising efforts on print ads in various fleet publications, supporting product brochures, Internet website marketing ads, and direct active participation in alternative fuel vehicle promotional events such as EV expositions, auto shows, and "ride and drives". Some marketing themes that Toyota has used include "all the comforts of a RAV4 but none of the gas, oil, exhaust…", "the technology may be new, but the reliability is Toyota through and through" and " you may not be able to tell you're driving an electric vehicle. But the environment can."

In April 1999, Toyota announced that it had placed enough vehicles to satisfy its MOA commitment. Toyota continues to produce a limited number of additional vehicles beyond the required MOA level, and will continue product development and the collection of in-use information about range, performance and market acceptability of the RAV4 EV.

7.2.2 Early Market Placement Results

This section describes the results of the initial EV marketing efforts by the major manufacturers.

In public comments, manufacturers pointed out that for many months, when all manufacturers had products available, vehicle inventory greatly exceeded the demand for vehicles. For example, when GM first introduced the EV1, “the majority of 1997 was characterized by steadily increasing inventory, throughout the first three-quarters of the year. There was a backlog of over a year’s supply on hand that needed to be marketed and sold. The following year, sales remained at a steady but low level. All told, the number of days' supply of EV1s averaged over 200 days 80 percent of the time during the first two years of EV1 production. This level exceeds the norm of 60 days supply by over three times. There were excessive levels of inventory available for over 2 years.”

Honda, the other manufacturer that offered vehicles to the general public, noted that both GM and Honda had experience of 2 years or more of retail EV promotion and availability with very little response from the general public despite significant marketing campaigns.

Several manufacturers observed that from their standpoint the sale of EVs has been very labor intensive and expensive relative to conventional vehicles. For example, sales staff need extensive training, additional time and effort is needed to educate customers regarding new technology, the ratio of sales to initial inquiries is low, and much time and effort are needed to deal with infrastructure installation issues. These manufacturers indicated that the time it took to place the MOA vehicles, the lease rate adjustments made for marketing purposes, and the incentive programs offered reflect a limited fleet niche EV market. They conclude that a general EV market does not exist that would be profitable for EV dealers even with considerable support from the manufacturers for marketing, promotional materials, and sales staff and automotive technician training. In general, manufacturers argued that there are fundamental challenges to placing EVs at the required levels, due to high cost, limited range, long recharge times, value/cost perceptions and the difficulties inherent in achieving widespread market penetration with a new technology.

Meanwhile, some parties have argued that the manufacturer marketing and sales efforts were intentionally half-hearted and ineffective. Staff does not subscribe to this viewpoint. Rather, staff concludes that the manufacturers made good-faith efforts to meet their MOA demonstration vehicle placement obligations. The manufacturer strategies and efforts have, after all, been successful in accomplishing their intended purpose. All MOA vehicles produced to date have been placed, and at present the number of interested customers exceeds the number of vehicles available. Through the MOA program manufacturers gathered valuable information regarding EV customer preferences and needs.

7.2.3 Measures of Customer Satisfaction

In assessing the results of EV marketing to date, it is important to review the experience of those drivers using the vehicles that have been placed. One clear message provided at both workshops is that those who drive electric vehicles are extremely happy with them. Numerous drivers took personal time off from work and journeyed to Sacramento and Diamond Bar just to emphasize their satisfaction with their vehicles and their desire that the availability of ZEVs be expanded. Drivers appreciate being able to drive without directly contributing to smog, fuel spillage, climate change, or other pollution problems. In addition to such societal benefits, drivers also mentioned many desirable attributes of the vehicles that are enjoyed in everyday commuting. Drivers spoke of the convenience of home charging, the smooth, quite acceleration, the low operating cost, and vehicle reliability.

In public comments, manufacturers noted that the EV drivers who testified at the workshop do not represent the population of California vehicle purchasers. This group has already self-selected to be EV owners with lifestyle and driving conditions that are acceptable to the category, and are willing to be the first to invest in new innovations. Staff agrees surveys of EV owners and drivers do not allow conclusions to be reached on market penetration of EVs, because the surveys do not include non-owners. That is, the sample is not representative of the vehicle purchasing population in California. Nevertheless such information provides important insights to manufacturers, regulators and future customers on the utility and viability of EVs in the "real world". Lessons learned with the EVs placed to satisfy MOA obligations can be used to better define the future EV marketplace by educating potential customers, identifying necessary technology improvements, and identifying desirable EV platforms.

Various organizations, including the manufacturers, have surveyed the selected individuals or agencies that have received MOA EVs. ARB staff received testimony at the May 2000 workshop regarding a recent major statewide survey of EV drivers. Staff also received testimony at the March 2000 workshop regarding several Internet-based surveys of EV drivers. The results of these past surveys and surveys planned in the near term are briefly described here.

<u>March 2000 EV Owners Survey By the Mobile Source Air Pollution Reduction Review Committee (MSRC) and Air Districts</u>

The Mobile Source Air Pollution Reduction Review Committee (MSRC) was created by the California Legislature in 1990 to oversee programs, funded by a $4 motor vehicle registration fee, to reduce air pollution from mobile sources pursuant to the California Clean Air Act and the local Air Quality Management Plan. In March/April 2000, the MSRC and five air districts conducted a survey of electric vehicle owners. The focus of this comprehensive survey effort was to understand how EVs are being used in both retail and fleet applications. Results of the survey will lay the foundation for a statewide EV Education Program, funded by the Department of Energy (DOE) through the California Energy Commission (CEC) and administered by the Clean Car Education Program (CCEP).

For the past several years, five air districts partially funded by the CEC to provide EV incentives have been required to survey incentive recipients and report the results to the CEC on a biannual basis. The recent survey project took that activity one step further by looking at the results statewide, rather than district by district, and by evaluating the results along with those of other past surveys conducted on this subject. As the CCEP gets off the ground, it will be important to have a clear idea of who the first EV drivers are and the vehicle attributes that they most appreciate. This information will assist the CCEP in developing messages for the public concerning electric transportation.

- A total of 294 surveys were received, which reported on 311 electric vehicles (an overall survey response rate of 49.5 percent, as compared to the response rate of 35 percent for a 1998 MSRC survey).
- Fifty-two percent of the vehicles were from the South Coast Air Basin (Orange County and non-desert portions of Los Angeles, Riverside, and San Bernardino counties); 31 percent were from the Bay Area, while the remaining vehicles were from Sacramento, San Diego, Santa Barbara, Ventura, and San Luis Obispo counties.
- Fifty-eight percent of vehicles reported were EV1s.

Surveys were distributed to fleet operators and retail consumers. Owners were requested to complete the survey on existing and previously owned electric vehicles. Therefore, owners whose vehicles have been recalled, or owners whose leases have expired, are also included in the responses. Sixty eight percent of the vehicles were 1998 or 1999 model year, twenty-two percent were 1996 or 1997 model year, and ten percent were 2000 model year or not specified. The annual average miles driven was 7,700.

Specific findings reported by the MSRC include the following:

<u>Vehicle Usage</u>.

- Fourteen percent of respondents reported they drove their EV over 50 miles per day.
- Ninety-one percent state that they use a freeway weekly if not daily; of the total, forty-two percent reported driving on the freeway on a daily basis. Only eight percent indicated that they never access freeways while driving their electric vehicle.
- Seventy percent indicated that they use their EV as their primary vehicle, and of those, ninety-three percent have another vehicle available to them, but they prefer to drive the EV as their primary vehicle.
- Owners use their electric vehicles in variety of ways:
  68 percent for work or school commuting purposes,
  64 percent for shopping and/or errands during the week,
  55 percent for work-related purposes during the week, and
  41 percent for weekend or recreational purposes.
- Fifty-one percent of respondents (56 percent in the SCAB) indicated that they use public charging stations at least once a week. Forty-nine percent (67 percent in the SCAB) reported they drive their EV much more or somewhat more because public charging is available. Sixty-four percent (69 percent in the SCAB) reported that they did not have workplace charging but would use it if they did.
- Table 7-3 shows that a large percentage of drivers use their EVs more than they thought they would prior to acquisition. Currently, seventy-four percent indicated that they drive their EV more than 75 percent of the time.

Table 7- 3: Percentage of Driving in EV		
Proportion of Driving	Expected, Prior to Ownership	Actual, After Ownership
Less than 25%	10%	7%
26% to 50%	20%	6%
51% to 75%	15%	7%
76% to 100%	46%	74%
No Response	9%	6%

Owners' EV Experience.

- Eighty-percent of those surveyed were more satisfied with their EV than with their current gasoline car.
- Drivers indicated that overall they were extremely satisfied with their electric vehicles.
- Features contributing to drivers' satisfaction include appearance and acceleration.
- Drivers are only partially satisfied with vehicle driving range and heating system. (The MSRC survey description combines both range and heating system. Looking at the survey results for driving range, staff found that 74 percent of the drivers indicated that they were satisfied, very satisfied, or extremely satisfied with the range of the vehicle.)
- Limited vehicle range, lack of public awareness and marketing are considered to be the most important reasons why the number of EV leases have not been greater.
- Forty percent (55 percent in the SCAB) indicated that one time in four, drivers find a gasoline-powered vehicle parked in a public charging stall.
- Sixty-three percent of respondents reported that incentives were a very important or somewhat important factor in influencing their decision to lease an EV.
- Seventy-seven percent would lease another EV***.***

EV Owner Demographics. EV owner demographics are very similar to those indicated in the 1998 MSRC survey, as well as other surveys conducted to monitor the use of electric vehicles throughout the state.

- 72 percent of the primary drivers were male and 18 percent were female. Nine percent of the respondents reported that both male and female members of their household were the primary driver, and one percent did not respond. The percentage of women drivers has increased since previous surveys.
- Forty-seven percent of EV drivers are 35-50 years old.
- The majority of respondents indicated they were employed as business (31 percent) or technical (23 percent) professionals. Ten percent were retired.
- Fifty-eight percent of respondents reported an annual income of less than $150,000.

August 1998 Electric Vehicle Owner Survey by the MSRC

In mid-1998, the MSRC distributed a survey to 284 EV Owners/Lessors who took advantage of the MSRC's buy-down incentive. 106 surveys were returned (36 percent response rate). The majority of the respondents were most likely retail customers, given that 77 percent of the surveys received were from drivers of the EV1. The average length of ownership was slightly more than 13 months, and the average annual mileage was about 8,100.

The survey focused on characterizing the EV driver and EV use. 82 percent of the EV drivers were male. The EV was typically the primary car in a household with more than one vehicle. When asked why they leased their EV, the top three responses were (1) concern for the environment or a desire to do their part to help clean the air, (2) a desire to be one of the first to adopt an up and coming technology, and (3) a good fit between the EV's range and their commute patterns and habits. Based on the survey, the EVs appeared to meet a wide variety of transportation needs:

- Commute to and from work or school (71 percent)
- Work/business purpose during the work day (63 percent)
- Shopping, errands during the week (88 percent)
- Family trips/outings, errands on the weekend (75 percent)

EV1 Drivers Club Survey

Testimony was received at the March 2000 workshop regarding an online survey conducted via the EV1 Club Internet list. It was reported that about 130 persons took the survey with over 80 percent driving EV1s and the remainder driving the Honda EV Plus and Ford Rangers. Vehicle usage and owner experience were similar to that described above for the MSRC surveys. This survey additionally queried the drivers for their opinion on the importance of various factors affecting public acceptance of EVs. The majority of drivers reported that:

- Public awareness, the cost of the EVs, range, and availability of EVs are extremely important or most important factors.
- The variety of EVs and lease-only placements were not important or somewhat important.
- The minimum guaranteed daily range to make an EV practical would be between 60 and 100 miles.
- Advertising and marketing of EVs by automakers has not been effective.
- The public has not been effectively educated regarding EVs.
- EVs have not been effectively made available to the public.

EV Driver Testimonies on the Internet

At the March 2000 workshop, staff received a package of more than 80 EV driver testimonials that had been collected from several Internet sites. These were primarily testimonials on the driver experience with leased or rented EV1s and the EV Pluses, but did include some for the Ford Ranger, conversions and even the Toyota Prius hybrid electric vehicle. The drivers were consistently pleased with vehicle performance, ease of driving and recharging, lower fuel and maintenance costs, and the minimal maintenance requirements. The drivers found vehicle range more than adequate for their typical daily needs, Many drivers hoped to retain the EVs after the current leases expire and expressed strong support for the ARB's ZEV requirements.

Air Resources Board Internal User Survey

The ARB Test Fleet, described further in Chapter 6.4.1, makes vehicles available to ARB employees for a period of two days up to a week. From July 1997 to August 1999, 245 employees made more than 2,800 trips with the test fleet. Two popular test fleet vehicles, a Honda EV Plus and a GM EV1, have been driven more than 25,000 miles and 20,000 miles, respectively. The employees were asked to complete a survey regarding their experience with each EV model. Analysis of 141 surveys returned by 99 employees indicates that the respondents typically had a positive to most positive overall experience driving the EVs. About 60 percent of the respondents indicated that they would consider leasing an EV for personal use. Some respondents identified several factors that they considered as impediments to leasing, including limited range, cost, and the inconvenience of charging. However, it should be noted that the test fleet user does not typically have access to a charger at home and must share access to chargers at work.

To date, one staff person at ARB has successfully leased an OEM EV, a Ford Ranger; several staff own electric conversions. In recent months, the ZEV Implementation Section at ARB has had a noticeable increase in the number of inquires from ARB and other governmental agency staff regarding the availability of EVs to retail customers. This increased level of interest seems to coincide with publicity regarding new HOV access for EVs beginning July 1, 2000, and increased awareness of free EV parking at many public garages serving business and governmental centers. Awareness and interest in leasing EVs continue to build within the ARB and other state agencies.

Office of Fleet Administration Daily Rental Electric Vehicle Survey

The Department of General Services, Office of Fleet Administration operates several State garages that provide daily and long-term vehicle rentals to state agencies. Since July 1997, the State garage in Sacramento has offered free daily rental of the Honda EV Plus and the GM EV1. As of October 1999, more than 525 round trips, averaging 20 miles, have been made with a fleet of five EVs. The EV users were given the opportunity to complete a short survey on their EV driving experience. ARB staff analyzed 70 surveys turned in over a several month period in mid-1999. All of the respondents indicated that they were satisfied with the overall performance of the EV and that the driving range of the EV met their needs (for the rental). Almost 70 percent indicated that they would consider leasing or buying an EV. The most frequent comment received was that the EV was easy to drive and performed well. 10 of the 84 respondents also mentioned that the range was too limited for full-time use.

Southern California Edison Fleet Experience and Municipal Fleet Survey

SCE Fleet Experience. SCE staff testified at both workshops regarding the SCE's successful 12-year demonstration of a wide variety of EV models and prototypes. Overall EV penetration of the SCE's entire light duty fleet is more than 11 percent with some business units over 60 percent. By early 2000, more than 4.5 million miles had been placed on more than 420 EVs. SEC took a "mission match" approach to marketing and placing the EVs within their fleet. In a SCE questionnaire, 50 percent to 100 percent of the drivers responded that their EV was suited for their application and reliable, available 97 percent of the time. According to maintenance records, the highest incident repairs are related to tire replacements (49 percent), auxiliary systems (11 percent), batteries (10 percent), and charger (9 percent). SCE also found that operating an EV is less costly than operating a gasoline vehicle due to lower fueling costs and maintenance requirements.

According to SCE staff, the process of expanding its EV fleet has had its challenges. SCE staff identify several areas of improvement necessary to allow EVs to reach their full potential, including the need for efficient and reliable EV ordering and delivery, standardized EV charging equipment, and availability of vehicle parts. Having found that EVs work successfully in their fleet applications, SCE staff plans to place an additional 200 EVs each year in the fleet, but are concerned with declining product availability.

SCE Municipal Fleet Survey. In 1999, Southern California Edison surveyed a total of 63 municipal agencies, colleges and transit agencies regarding their experience with their EV fleets. These fleets had a total of 178 EVs including the Chevrolet S10, Ford Ranger, GM EV1, Honda EV Plus, and Toyota RAV4. These agencies also had 67 vehicles in the acquisition process. These vehicles are typically used for administrative, enforcement and inspection purposes or as pool/loaner vehicles. On a per vehicle basis, 84 percent of those surveyed were satisfied with the operation of the EV. Areas of dissatisfaction included reliability, range and seat/payload capacity. While 96 percent of the agencies were interested in expanding their EV fleets, the respondents cited cost (33 percent) and performance/range (53 percent) as barriers to greater EV use.

EV Rental Cars Electric Vehicle Customer Satisfaction Survey

EV Rental Cars, in conjunction with Budget Rent-a-Car, provides rentals of electric and alternative fuel vehicles at several locations in California including the Los Angeles, Sacramento, and Ontario airports. EV Rental conducted phase one of an Electric Vehicle Customer Satisfaction Survey in May 2000. The sample in phase one consisted of 29 electric vehicle renters. The number of males surveyed outnumbered the women surveyed by 6 to 1, and most of the rentals were for business purposes.

The overall experience of the electric vehicle renters was very positive. Of those surveyed, 93 percent were satisfied with the overall performance of the electric vehicle. Almost 80 percent said the vehicle's driving range met their needs and 76 percent said they would consider leasing or buying an electric vehicle. The customers indicated that they chose to rent the EV because driving it is better for the environment (41 percent), they were interested in the new technology of the EV, and the cost of the rental was less than expected (12 percent). EV Rental indicated that phase two of the survey will be available in mid-August 2000.

May 2000 Electric Vehicle Fleet Managers Workshop Survey

On May 23, 2000, Southern California Edison conducted an EV Fleet Managers Workshop, inviting more than one hundred representatives of municipal fleets, transit agencies, universities, and private businesses in the South Coast Air Basin. In response to an initial survey attached to registration materials, the fleet managers identified nine issue areas for discussion at the workshop including vehicle reliability, maintenance support, manufacturer support, operator and maintenance training, delivery delays, vehicle range, infrastructure, costs, and vehicle appropriateness. An expanded survey and evaluation form was developed and used at the workshop for roundtable discussions, moderator-led discussion, and written responses. The response rate was about 50 percent including follow-up telephone communications. Tabulated results and a summary of remarks are described in a report prepared by The Planning Center, "EV Fleet Issues: Perspectives of Fleet Managers". The report concludes that non-availability is the largest concern of EV fleet managers, and that this issue is critical to continuing EV market growth and overshadows the other concerns of reliability, maintenance support and limited range. The report further concludes that the future of the EV market is still very dependent upon government mandates and incentive programs, and that continued financial support for the incremental cost of vehicles and expansion of the EV infrastructure is needed.

7.2.4 Marketing Issues

This section touches on various issues that have arisen in the course of the initial EV market demonstration programs.

Vehicle Availability. Many speakers at the workshops testified that although they are interested in leasing an EV, they have been unable to do so because vehicles are not currently available. For example, drivers who lost the use of an EV1 due to the General Motors recall, and who wish to replace the EV1 with another electric vehicle, have in most cases been unable to do so. A fleet manager for a major utility testified that he anticipated having difficulty meeting his desired lease level of about 200 EVs annually, and another fleet manager reported similar problems. Staff has received public comment documenting that fleet managers for at least 14 other private and public fleets would like to lease a total of more than 40 vehicles, but cannot due to lack of availability. The affected fleets include at a minimum the following:

- City of West Covina
- City of Burbank
- City of San Francisco
- City of Santa Rosa
- City of Newport Beach
- City of Huntington Beach
- City of Pasadena
- Xpress Shuttle
- VTA
- Novell
- Anaheim
- Anaheim Transportation Network
- Los Angeles Department of Water and Power
- City of West Hollywood

ARB staff has experienced this problem first-hand, in that ARB has been unable to obtain the desired number of vehicles for the EV Sacramento and EV Loan programs, which place EVs with government agencies. This lack of availability of electric vehicles is due to the decision by most manufacturers to curtail production after placing the vehicles required for their MOA demonstration programs. Toyota and Ford are still taking orders to be filled next year, with one experiencing production delay because of a component supply problem.

The MOAs were originally intended to provide a ramp-up to 2003. In retrospect, it appears that the combination of the MOAs and the existing level of multiple credits offered for early introduction have not been sufficient to encourage significant vehicle production in 2000 though 2003.

Lease Process Difficulties. Staff has received testimony and written submittals from individuals indicating that in their view they had to overcome unusual barriers in order to lease an EV. Examples included sales staff who are unfamiliar with the vehicles, long delays in getting information, ambiguous or contradictory information regarding “waiting lists” to obtain vehicles, and long delays in getting vehicles once orders had been placed. Some EV drivers also stated they have more recently stopped encouraging potential customers to visit EV dealers, because test drive opportunities are difficult to arrange and the dealers are uncertain regarding when EVs would be available.

Regarding delays, Ford testified that some of its delays in vehicle availability were due to quality control issues and supplier problems, which occur on conventional vehicles as well. Manufacturers also stated that the only additional barriers or delays specific to acquiring an EV are attributable to issues regarding the proper installation of home recharging sites. Charger installation involves an initial inspection of the site, contractor installation, and local agency inspection to ensure all aspects are safe and meet local code requirements.

7.2.5 Applicability to 2003

All major manufacturers have placed vehicles in response to the MOAs between the automakers and the ARB. Under the MOAs, the automakers committed to participate in an advanced technology battery demonstration project. Each automaker agreed to produce their pro-rata share of approximately 1,800 advanced battery vehicles between 1998 and 2000. In addition to the MOA vehicles, several manufacturers have also offered vehicles on a voluntary basis, separate from the MOA requirement. Such vehicles include the lead acid versions of the Chevrolet S-10, Gm EV1, Ford Ranger, and Chrysler EPIC, as well as the NiMH Toyota RAV4 EV.

Although manufacturers have devoted great effort to these placements, as described elsewhere in this section, ARB staff believes that the marketing of electric vehicles to date has differed from a normal market in several significant respects:

- Only two manufacturers, GM and Honda, offered their vehicles to retail customers with broad-based marketing efforts. The remaining manufacturers marketed only to fleets, using a marketing approach appropriate for fleet sales.
- Although a variety of vehicle platforms was produced, none of the manufacturers chose to develop a five passenger four door sedan.
- Manufacturers used a variety of approaches to sell, distribute and service the vehicles, but no manufacturer marketed its vehicles at all dealerships.
- Due to the new technology employed, EVs imposed unusual information and training demands on all involved parties--customers, dealership staff, infrastructure providers, and marketing staff.
- Manufacturer pricing strategies were intended to gather information about customer demand, but were not set in a competitive fashion based on prices of otherwise equivalent conventional vehicles.
- Most vehicles were available for lease only rather than for purchase, and some leases included low mileage caps of 10,000 miles per year..

Staff recognizes that there were valid reasons for all of these choices. For example, range, cost and packaging trade-offs entered into the choice of vehicle platforms, and low volume vehicles are often made available through only a limited number of dealerships in recognition of the training and expertise necessary to support unique vehicles. Staff is not criticizing the approaches that were taken, but rather pointing out that in some respects they were not typical of mainstream vehicle marketing.

Manufacturers have stated that it was difficult to place the relatively small number of MOA vehicles. The manufacturers then go on to conclude that based on their MOA experience it will be almost impossible to meet the 2003 requirement. They argue that fundamental EV marketing difficulties associated with battery technology, cost, vehicle range and customer preferences will not change in any significant respect between now and 2003.

Staff believes, however, that the results of the MOA marketing efforts, with vehicles priced well above similar conventional vehicles, do not necessarily indicate that a broad based approach from all manufacturers, with competitive pricing, could not succeed. When Ford reduced its price on the EV Ranger, for example, the available vehicles were quickly placed.

In summary, the MOA marketing efforts provide an opportunity to begin to understand the factors involved in advertising, selling and supporting electric vehicles. Lessons have been learned which will be of value in future efforts. The MOA experience does not, however, lead to definitive conclusions about the prospects for 2003.

7.3 The 2003 Market

This section reviews available information that will assist in assessing the potential market for EVs in 2003 and beyond. It addresses customer awareness, studies of market demand, and possible applications well suited to the use of EVs.

7.3.1 Customer Awareness

Testimony at the March and May workshops addressed the general point that it has been difficult for the public to get information regarding available electric vehicles and their characteristics. Drivers testified that their neighbors, friends and interested persons on the street do not know that production EVs are available to "regular people." These EV drivers expressed concern with the adequacy of manufacturer marketing efforts and government agency educational programs. In their public comments, automakers pointed out the aggressive measures that they have taken to provide information regarding their electric vehicles, including websites, television and newspaper advertisements, and toll-free telephone lines.

The level of public awareness was addressed in a more systematic way in recent research on EV Market awareness conducted by the Pacific Gas and Electric Company (PG&E). To determine the extent of target-market awareness of available light-duty, highway-legal EV products, PG&E surveyed a random sample of its residential customers. For seven consecutive weeks beginning on March 28, 2000, surveys were mailed each week to 450 residential customers. Of the 3,150 surveys mailed, 737 were completed by June 9, 2000 (23 percent response rate). PG&E assumed that the EV manufacturers are targeting California residents who are 25–54 years old with at least some college education. EV marketing effectiveness was evaluated for this subset of respondents. Data on income were not collected.

The survey consisted primarily of questions about customer satisfaction with Pacific Gas and Electric Company's service, but included two EV and three demographic questions. Introductory text immediately prior to the EV questions provided background. Awareness of available EV products was measured with multiple-choice questions: "Which, if any, companies do you think are selling or leasing EVs today in California? (Please check all that apply)" and "Which, if any, types of electric vehicles do you think are being sold or leased today in California? (Please check all that apply)." Survey respondents were deemed to be aware of EV products if they checked a correct combination of EV company and type.

EVs have primarily been promoted in marketing campaigns by EV manufacturers. Incentive programs by government agencies and education efforts by EV industry organizations, environmental advocacy groups, and electric utilities complement the automaker marketing campaigns. Despite these EV marketing activities, in Northern and Central California awareness of available light-duty, highway-legal EVs is low. Only 7 percent of the target group (25–54 year old, college-educated) in Northern and Central California are aware of at least one of several EV products. In the San Francisco Bay Area only 9 percent of this group in are aware of at least one EV product.

The researchers concluded that before EV range, operation and maintenance, and user satisfaction become important considerations to the consumer, the market must become aware of the product's existence. With so few people aware of available products, it is premature to make conclusions about the sufficiency of EV market demand.

7.3.2 EV Market Studies

Testimony was received at the May 2000 workshop regarding several market studies that have been sponsored by automakers or other interested parties.

Brief descriptions of the market studies are provided below. It should be noted that the studies are in progress or preliminary and have not been reviewed by ARB staff.

National Economic Research Associates

Toyota and General Motors recently sponsored a study of customer choices among internal combustion engine vehicles (ICEVs) and electric vehicles. The study was conducted by a researcher at the University of California, Berkeley and National Economic Research Associates, Inc. (NERA). The study's objectives were to determine how customers value electric vehicles relative to internal combustion engine vehicles and the impact of additional information on customers' valuations. According to workshop testimony, this study was conducted over the telephone with materials mailed in advance; respondents were not given the opportunity to test drive an EV. A sample of over a thousand recent new car buyers (cars purchased within the last three years) were given choice situations that varied vehicle attributes including vehicle type, engine type, purchase price, operating cost, performance and range. The respondents were split into basic and enhanced information level groups; the enhanced group was provided an air quality write-up and an article on EVs and ICEVs. The researcher used a mixed logit method to evaluate the response as varying vehicle attributes.

The study found a low demand for EVs because customers place a large negative valuation on EVs for reasons other than their price, performance, and operating costs. The study estimated that customers would require a $28,000 price differential in order for 50 percent of customers to choose the electric RAV4. Describing the impact of the negative valuation, the researcher indicated that since the average retail transaction price of an internal combustion engine Toyota RAV4 is about $21,000, this would mean that the average consumer would not accept a RAV4 EV if it were offered for free. According to the study, this is due to shortcomings that are characteristic of EVs, such as limited range. The researcher also indicated the negative valuation is still significantly strong even when consumers are informed about the potential positive effect of EVs on California air quality.

In staff's view, the reported finding that a typical customer would not accept a free RAV4 EV is counterintuitive to say the least. With a waiting list for ZEVs at lease rates of $450 per month or more, clearly many customers would be happy to get a free RAV4 EV. We also have numerous questions regarding the study methodology. Toyota and GM plan to provide staff with a copy of the report and a briefing by the researchers but this information has not been received in time to be included in this Staff Report.

Green Car Institute Market Research

The Green Car Institute is an independent, nonprofit agency created to further the acceptance and adoption of low emission and clean fuel vehicles by American motorists. Green Car Institute is engaging in a study to investigate the current and future market for electric vehicles, taking into account the state's experience up to now and likely experience in light of the mandate for 2003. In preliminary market research, Green Car Institute found that a variety of barriers have combined with the nature of the MOA demonstration projects to limit penetration of electric vehicles during the past several years:

- Fleet buyers are confronted with a different purchase process for EVs.
- Fleet availability and suitability of EVs is not marketed consistently.
- Private buyers are also confused and misled by EV marketing.
- Private buyers also encounter a more difficult buying process.
- Manufacturers' strategies may have been shaped more by the desire for quick fulfillment of MOA requirements than by long-term establishment of an EV market.

The Green Car Institute study will use standard automotive market research techniques to estimate the magnitude of the current and potential future markets for EVs. The variables will include current and future EVs with a variety of ranges, lease/sale prices and other attributes. Green Car Institute expects to be able to extrapolate the potential EV market and compare that with placement numbers required by the ZEV regulation. The study is expected to be completed prior to the September Board meeting.

7.3.3 Potential Market Applications

To attempt to provide useful information regarding the possible market in 2003, staff has investigated several applications that lend themselves well to being served by electric vehicles.

For this exercise we assume that the vehicle price would be roughly equivalent to similar conventional vehicles on a lifecycle cost basis. Manufacturers have argued that the price of EVs will need to be less than that of similar conventional vehicles, due to the limitations on EV driving range and recharge time. Ford commented that based on customer response to several different prices set for the Ranger EV, in order to meet a 4 percent mandate volume, Ford would have to set the price of the Ranger EV well below $200 per month. The $200 per month lease price corresponds to a manufacturers' suggested retail price (MSRP) of less than $10,000, as compared to the $14,000 MSRP of the conventional Ranger.

We recognize that at least in the initial years such pricing would not recover the cost of the vehicle. Consideration clearly must be given to how any additional costs would be borne. For our purposes here, however, we are investigating whether applications exist that could make use of the required number of vehicles, without regard to cost.

Fleet Vehicles.

Fleet sales include commercial, rental and governmental fleets. EVs are well suited to meet a variety of fleet applications. Fleet vehicles typically have well defined and consistent driving patterns and range requirements, and are centrally refueled.

Data from Automotive Fleet Magazine indicate that on a national basis, fleet sales make up about 20 percent of passenger car sales and 12 percent of truck sales. Fleet sales are 16 percent of the combined (cars plus trucks) total. Given California annual light duty vehicle sales of roughly 1,000,000 per year, a 16 percent sales fraction corresponds to a fleet market of about 160,000 vehicles per year. (Please note that this is a revised estimate as compared to the Preliminary Draft Staff Report, based on new information). Thus a 10 percent penetration of the fleet market, or 16,000 vehicles per year, would in and of itself almost be sufficient to meet our estimated “base case” four percent ZEV placement requirement.

Staff has attempted to gather more specific information as to the number of fleet vehicles purchased per year in California by various fleet operators. Information on such purchases is scattered, and to date staff has been unable to obtain precise estimates. The following represents the best available information available at this point.

Automotive Fleet Magazine data, again at the national level, indicate that governmental fleets make up 7 percent of passenger fleet sales, 12 percent of truck fleet sales, or 9 percent of total fleet sales. Using the 160,000 vehicle annual California fleet sales estimate noted above, 9 percent of that total is 14,400 vehicles per year.

Excluding special purpose vehicles such as those used by the California Highway Patrol, the State of California purchases roughly 1,500 passenger cars and light duty trucks per year. Based on 1991 survey results reported by the California Energy Commission, staff estimates that local governments (cities and counties) purchase roughly 14,000 light duty vehicles per year. This total does not include special purpose vehicles such as police cars. Taken together these state and local government fleet sales total more than 15,000 vehicles per year. This estimate is in general agreement with the 14,400 figure for governmental fleet sales derived above. If electric vehicles could serve one fourth of these governmental applications, it would result in a market of about 3,750 vehicles per year just for state and local public fleets.

Utility companies represent another ideal market. A representative of Southern California Edison testified at the March 2000 workshop that EVs already constitute more than 11 percent of their total light duty vehicle fleet, and more than 60 percent of some business units. SCE plans plan to add 200 vehicles per year. Staff estimates that by 2003 utility companies statewide could readily absorb 1,000 vehicles per year.

The federal government vehicle fleet and other large institutional fleets such as the US Postal Service also could readily use EVs. Staff does not have quantitative information at this point, but notes that it is reasonable to assume that other fleets could make use of EVs in a manner similar to utilities and governmental fleets.

Commuter Vehicles/Second Cars.

To attempt to quantify the number of households that could reasonably be expected to use an EV for commuting purposes, staff has adapted a methodology used by auto manufacturers. The elements of the calculation are as follows:

Number of owner-occupied households in California with two cars and garage	3,800,000
Percentage of above with annual household income greater than $75,000	x 17%
Result	646,000
Percentage of above with round trip commute of 40 miles or less	x 68%
Result	439,280
Percentage of above that purchase a vehicle in a given year	x 20%
Result	87,856

These assumptions are deliberately somewhat conservative. For example, households with annual income below $75,000 certainly purchase cars, and some fraction of them could be attracted to an EV. Even so, this calculation results in a target population of almost 88,000 households. If 5 percent of these households chose to lease an electric vehicle for commuting or second car purposes, it would result in a market of about 4,400 vehicles per year.

City Electric Vehicles.

Ford Motor Company, through its Th!nk subsidiary, plans to market the Th!nk City vehicle beginning in 2001. The market for City Electric Vehicles is promising but largely unexplored.

Low Speed Vehicles.

As discussed in Section 4 above, low speed vehicles are not passenger cars under federal law and do not need to meet the same Federal Motor Vehicle Safety Standards. These vehicles do, however, qualify for ZEV credit. The market for low speed vehicles in California also is unexplored at this point. Proponents have noted that there are large numbers of retirement communities, universities, business campuses, gated communities and other developments that provide a potential niche for this type of vehicle.

Summary

As the technology has advanced and vehicle makers have adapted to current circumstances, it appears that a wide range of vehicle types will be available in 2003. Staff has described various applications that lend themselves to being served by EVs. Staff acknowledges that the assumptions underlying these estimates may be deemed overly conservative or overly optimistic depending on one's point of view.

Manufacturers have commented that "potential applications" are not the same as "market demand". Manufacturers also stated in public comments that the staff estimate of potential market is not well supported by data. Staff recognizes that placement of the required number of vehicles in the possible applications noted above will be difficult, because customers have many attractive choices available that do not have the range, recharge time, and cost limitations associated with today's battery electric vehicles. Staff does not agree, however, that market demand is non-existent for competitively priced ZEVs.

7.4 Elements Needed for a Successful EV Market

This section outlines several elements that will be essential in order for the EV market to progress. Before listing these marketing needs, however, it is necessary to understand some of the unique attributes of the EV market that need to be taken into account.

7.4.1 Attributes of the EV Market

Real vs. Perceived Range Needs.

Many drivers remarked that when they first considered an EV, they had an estimate in mind regarding the portion of their driving that could be accommodated within the available range. After living with the vehicle, however, they learned that their actual driving patterns were less demanding than they had imagined, and therefore they were able to use the EV far more than they had anticipated. Drivers noted that this “mismatch” between perceived and actual range needs is an artificial barrier to more widespread demand for EVs. Public information would help in getting customers beyond this perceived barrier.

SCE has developed an innovative electronic mapping tool known as the Trip Planner to help address range concerns within its own fleet applications. The software allows local fleet users to map their daily routes and confirm that they are within the range of an EV. The trip planner has been very effective in breaking down internal employee reservations about EV use. Districts that were reluctant to use EVs used the trip planner to analyze their trips and routes, and are now successfully using EVs.

Consumer Decisionmaking Regarding Lifecycle Cost.

EVs will have a higher up-front cost, offset by savings over time in fuel cost and maintenance. Consumers generally have shown, however, that they value up front savings more than savings achieved over time, even if from an economic standpoint the alternatives are of equal cost. For example, consumers do not always favor energy-saving improvements that clearly will pay for themselves over time. This behavior, although “irrational” in an economic sense, is real and must be addressed in order to achieve the full EV market potential.

Driving the Vehicle Increases Its Appeal.

Many members of the general public have preconceived notions regarding EVs--they are considered “golf carts” with limited driving appeal. At the March workshop drivers testified that once they had an opportunity to drive an EV, they were “sold”. The customer satisfaction attributes noted above (smoothness, quiet, performance, fun to drive) can only be experienced in person. Staff has noted a similar phenomenon in the operation of the EV loan program. Once fleet users have had an opportunity to drive the vehicle their acceptance of its possible application to their fleet is enhanced.

Public Perception of Hybrid Electric Vehicles.

Many members of the public also have inaccurate perceptions of the relative environmental attributes of EVs and hybrid electric vehicles. Staff has noted that in most cases the public assumes that hybrid electric vehicles are as clean as EVs. They thus conclude that hybrids have more appeal because they are just as clean but offer unlimited range and do not need to be recharged. In fact, although the efficiency of hybrid electric vehicles offers CO_2 advantages when compared to a standard vehicle, today's hybrids can emit more smog forming pollutants than the most advanced conventional vehicles, let alone EVs. For example, the Honda Insight is certified to the ULEV level, while Honda sells an Accord that is certified to the SULEV level. The Toyota Prius is certified as a SULEV.

Many factors go into the choice of a vehicle, and staff does not mean to imply that purchasers of HEVs would instead all opt for EVs if they fully understood the relative environmental attributes of the various vehicles. A better public understanding of these points would, however, increase the relative appeal of EVs to those customers for whom "green car" attributes are important.

<u>Risk of New Technology</u>.

EVs feature cutting-edge technology. For some customers, this is a positive benefit. The manufacturer marketing strategies noted above recognized that "early adopters" and "techno champs" would be favorably disposed towards EVs for that reason. For other customers, however, the introduction of new technology is cause for hesitation. Such customers, who ultimately may be well suited to using EVs, will need additional information and consultation. Manufacturers have tried to address this issue through lease packages that offer unlimited free maintenance and remove all risk from the consumer.

Additionally, successive market years of experience will increase the acceptance of EVs as they pass their first years as a new technology. Those who avoid driving cars in the first model year of a new design will more readily consider EVs as their history on the market grows. This may help explain the apparent growth in interest in EVs in the past year as the MOA vehicles began to accumulate their third and fourth years of experience.

7.4.2 Marketing Needs

Much public comment has noted that the primary factors affecting the marketability of EVs are range, recharge time, infrastructure, and price. Staff agrees with this assessment, and in particular staff believes that in order for the market to succeed it will be necessary for EVs to be available to customers at prices that are competitive on a lifecycle cost basis to similar conventional vehicles. Staff notes that manufacturer testimony indicates that in their view this is overly optimistic; rather they believe that EVs will need to be offered at prices significantly below those of gasoline vehicles in order to achieve the volume required by the mandate. Assuming that at least in the short term EV costs will exceed costs for conventional vehicles, it will be necessary to consider some combination of government incentives and manufacturer subsidies to close the gap.

In addition to range, recharge time, infrastructure and price, the overall context in which customers are making their purchase decisions is also important. In that light, staff has identified several factors that are critical to the ongoing success of the EV market.

Continuity.

Perhaps the single greatest need is for a smooth, orderly buildup from the current base of activity towards 2003. For the ZEV regulation to achieve its goals there must be a well defined path towards greater and greater fleet penetration. A great deal of effort has been expended to bring us to where we are today from the standpoint of infrastructure development, dealership training, public outreach, and other factors. At the moment, however, there is a large gap between the completion of the MOA placements and the beginning of the 2003 requirement, and few if any vehicles are available to customers.

During the 1996 Biennial Review, the transition between the MOA program, which ends in the year 2000, and the ZEV regulation, which begins in 2003, was the subject of much discussion. Some parties argued for specific percentage phase-in requirements for 2000 through 2002. The manufacturers resisted any pre-defined ramp-up requirements, arguing that flexibility was needed to accommodate differing manufacturer technical approaches and development timing. In the end, a flexible approach was adopted. Manufacturers have produced the required MOA vehicles, and there was a period of several years during which those vehicles were readily available. As the MOA obligations have been satisfied, however, product availability has declined. Today, despite waiting lists for vehicles, the flexibility provided in the ZEV regulation has resulted in only limited product being available.

In most cases, there is no evidence that manufacturers plan to produce additional vehicles, particularly for lease to the general public, between now and 2003. On the bright side, Ford is gearing up to market the Think City EV in 2001, and has already begun to run television advertisements. Ford also has indicated that it will continue to produce lead acid Ranger EVs. Toyota has stated that it will continue to produce the RAV4 EV, and is taking fleet orders for next year's production (the current year production is sold out). For the remaining manufacturers, however, staff is not aware at this point of any firm commitment to produce additional vehicles prior to 2003.

Staff is concerned that a "boom and bust" cycle could wipe out the progress that has been made, and create an irreversible impression in the public's mind that EV technology is a thing of the past rather than a preview of the future.

Mainstream Vehicle Platforms.

As noted above, staff recognizes that the choice of vehicle platform was the subject of a great deal of analysis and research by the manufacturers. It is noteworthy, however, that at present there is no four door, five passenger sedan available. In order to achieve ongoing annual market penetration at the required level, staff believes that it will be necessary to have additional vehicle platforms available. In their public comments, manufacturers argued that the addition of a five passenger, four door sedan would not significantly increase ZEV volumes, but rather would take volume away from other offerings. They also note that adding new vehicle platforms will increase costs, due to large fixed costs for design, development, validation, manufacturing, and marketing.

Public Education.

We have noted that EV customers likely will need information above and beyond what is typically required for a vehicle purchase. Topics to be addressed include typical real world range needs and driving patterns, the benefits of a lifecycle cost approach, and the environmental superiority of pure electric vehicles. Customers also are likely to require more extended test drives than are typically offered. Staff notes that the Toyota Prius marketing plan calls for “demonstrator” vehicles to be available to interested customers for an overnight loan. Manufacturers have emphasized demonstration vehicles in their fleet marketing approach for EVs. A similar approach to retail EV sales will likely be necessary.

A public education campaign would require significant investment.

Market to Retail Customers.

As noted above, several auto manufacturers restricted their sales and marketing efforts to fleet customers only. During the MOA period, this approach had certain advantages, and allowed those manufacturers to limit their training, service and support needs, provide more targeted customer service, and focus on a better defined and more predictable set of driving patterns. In order to achieve the required 2003 placement levels and have a sustainable market over the long term, staff believes that it will be necessary for all manufacturers to market to retail as well as fleet customers.

Broader marketing will, however, result in added expenses for marketing, advertising, dealership training, sales and service, and infrastructure.

8 COST ESTIMATES

8.1 Introduction

The preliminary draft version of this Staff Report outlined a methodology for calculating comparative lifecycle cost estimates for battery electric vehicles and near-term partial ZEV vehicles (hybrid electric vehicles and SULEV internal combustion engine vehicles). Examples were given that showed the application of the methodology for given sets of assumptions.

Staff now presents estimates of likely costs for several representative vehicle types. These estimates draw upon the work of the Battery Technical Advisory Panel, comments received on the panel report, comments received on the draft Staff Report, and other sources.

The cost estimates presented here include the cost of the battery, charging equipment, any unique EV, HEV or PZEV components, fuel, and maintenance for each vehicle type. It should be noted that in order to simplify the calculations and their presentation, this analysis only considers a subset of vehicle operating costs--those expected to vary significantly across vehicle types. Therefore, the estimates reported here are not directly comparable to other reported estimates of lifecycle cost per mile. Our methodology is intended to provide a relative sense of the lifecycle cost difference across different vehicle types, rather than an absolute estimate of operating cost per mile.

Estimates are provided for incremental initial cost (incremental cost of the vehicle plus the battery pack and charger) and for lifecycle cost per mile. Cost estimates are derived for freeway capable battery electric vehicles, city electric vehicles, gasoline-electric power assist hybrid vehicles, and PZEV gasoline ICE vehicles. Results are shown for 2003 production volumes, and for future high volume production (100,000+ units). Low speed electric vehicles are discussed qualitatively but no cost per mile figures are generated.

The vehicle types noted above are included because they are expected to be available in the 2003 timeframe. Because examples of these vehicles are in production today, more reliable cost information is available for them. Cost information for other advanced vehicles not expected to be in production in 2003 (e.g. fuel cells, or hybrids with all-electric range) generally is far more tentative at this point, and no estimates of such costs are developed in this document.

8.1.1 Cost, Not Price

Staff emphasizes that this methodology seeks to estimate the incremental cost of vehicle production and the cost of operation. This is not the same as estimating the price at which various vehicles would be offered for sale. Price is set in a competitive environment, and can differ from cost for a variety of reasons. In some circumstances companies may choose to set a price that is lower than their cost in order to encourage sales of a particular vehicle. Several possible reasons for such an approach were noted in a study by EPRI entitled Pricing for Success: EV Costing and Pricing. Companies may establish a price that encourages sales of a particular vehicle in order to:

- Foster a cutting edge or environmentally sensitive image.
- Capture customers from particular demographic segments.
- Improve the corporate average fuel economy (CAFE) result.
- Expand market share, overall and in particular market segments (e.g. fleets).
- Introduce new technology in a limited, controlled fashion.

8.1.2 Previous Analyses

The most recent detailed ARB assessment of electric vehicle operating cost was prepared in 1994 to support that year's Biennial Review. That assessment concluded that "the net present value of the battery and operating cost of an electric vehicle using a high-energy battery (in volume production) can be comparable to the net present value of the cost to operate a conventional compact car." Although certain assumptions are handled differently, from a methodological standpoint the cost calculations in this section follow the approach used in 1994.

Other analyses have also attempted to estimate the lifecycle cost of various vehicle types. A Review of Electric Vehicle Cost Studies: Assumptions, Methodologies, and Results (Lipman, 1999) critically reviewed eight EV cost studies performed from 1994 to 1999. This report summarized that "The EV cost studies…report somewhat disparate results. All studies conclude that EV costs will be higher than conventional vehicle costs in the near term, but a few studies suggest that EV costs could relatively quickly drop to levels comparable to those of conventional vehicles, particularly on a lifecycle basis. Most studies suggest that EV purchase costs are expected to remain a few to several thousand dollars higher than conventional vehicle costs, with lifecycle costs also remaining somewhat higher. Finally, one study concludes that EV purchase prices are likely to remain much higher than conventional vehicle prices, through 2010". In the critical review, Lipman notes various limitations in many of the studies reviewed, including the two that showed rapidly declining cost and the one that showed much higher EV cost.

The report went on to note that "Some of the variation in the reported results of EV manufacturing costs can be explained by considering the vehicle classes, production volumes, and battery types considered in the various analyses. However, aside from these critical study parameters, considerable variation remains in the vehicle purchase price and lifecycle cost estimates reported here. Uncertain parameters that help to account for the remaining differences in cost estimates include the assumed performance of the vehicle…, the cost of the assumed battery type, and costs of accessories and additional equipment needed for the EV".

Two additional studies have been published subsequent to the completion of the Lipman review. The first is entitled Evaluation of Electric Vehicle Production and Operating Costs (Cuenca, Gaines, and Vyas, November 1999), prepared by the Center for Transportation Research at Argonne National Laboratory. With regard to initial cost, this study concludes that "The initial cost of the EV is projected to be higher than that of the CV, even under the most favorable assumptions. The basic EV (excluding battery) could possibly be produced at a slightly lower cost than the CV, but the high cost of the battery pack contributes substantially to the EV's cost." The conclusion of the Cuenca study with respect to lifecycle cost is that "The long-term operating cost of the EV would be comparable with that of the CV, despite the projected low fuel prices. … Although the energy cost is much lower for the EV, the battery replacement cost would more than offset this advantage. Only after a decade or more of continuous development and volume building would the EV be able to show a slight advantage over the CV with respect to operating costs."

The second recent analysis is the Motor Vehicle Lifecycle Cost and Energy-Use Model (Delucchi, 2000), prepared for the Air Resources Board by the Institute of Transportation Studies, University of California, Davis. This model "designs" a vehicle to meet range and performance requirements specified by the modeler, and then calculates the initial retail cost and total lifecycle cost of the designed vehicle. The model uses detailed assessments of vehicle cost and weight, vehicle energy use, and periodic ownership and operating costs. The model calculates the performance and cost of twelve kinds of light-duty motor vehicles. For battery electric vehicles, results are presented for two kinds of vehicles (Ford Escort and Ford Taurus) and four kinds of batteries (lead acid, NiMH Gen2, Li-Ion, and NiMH Gen4).

With regard to initial vehicle cost, in all cases analyzed in the Delucci study the retail cost of the EV is higher than the retail cost of the comparison ICEV Taurus or the comparison ICEV Escort. The report notes that "the higher initial cost of the EV is due mainly to the high cost of the battery". From a lifecycle cost standpoint, one scenario (next generation NiMH battery, 100 mile range) resulted in a lifecycle cost competitive with that of the ICE vehicle. In the other cases analyzed, using this study's methodology, the cost of the battery resulted in a higher EV lifecycle cost.

The existing studies do not provide a consistent framework for assessing and reporting comparative vehicle lifecycle cost, nor do they report similar results, particularly for long term prospects. This lack of consistency underscores the difficulty and uncertainty associated with projecting future costs for evolving technology.

8.1.3 Methodology

The lifecycle cost analyses used in this report focus on a subset of vehicle operating costs—those costs expected to vary across vehicle types, and to have a significant effect on the total. Thus many other costs are not included, such as the cost of the basic vehicle platform, insurance, or vehicle registration. Because this analysis does not address all aspects of building and operating a vehicle, the estimates developed here are not directly comparable to other reported estimates of lifecycle operating cost per mile.

At the May workshop an automaker commented that the "base case" for cost comparison should be a SULEV vehicle rather than a PZEV vehicle, because the SULEV more closely represents the typical 2003 fleet vehicle. This suggestion has been adopted.

Staff's analysis takes into account the following costs, aggregated over a ten-year vehicle life:

<u>Battery electric vehicle</u>:
Battery pack cost
EV incremental cost (incremental cost of unique EV components other than the battery, as compared to a SULEV)
Fuel cost (electricity)
Maintenance cost
Charging equipment cost

<u>Power assist hybrid electric vehicle</u>:
Battery pack cost
HEV incremental cost (incremental cost of unique HEV components other than the battery, as compared to a SULEV)
Fuel cost (gasoline)
Maintenance cost

<u>Internal combustion engine vehicle</u>:
PZEV incremental cost (incremental cost of unique PZEV components other than the battery, as compared to a SULEV)
Fuel cost (gasoline)
Maintenance cost

The identified costs are totaled over the ten-year life of the vehicle, then discounted back to present dollars. This discounted sum is then divided by the number of miles traveled to give a net present value cost per mile. In this analysis, we assume 10-year lifetime vehicle miles traveled of roughly 117,000 miles, based on the standard ARB emission inventory estimate, for all vehicles other than city EVs. Lifetime vehicle miles traveled for city EVs is assumed to be 75 percent of that for freeway capable vehicles, or about 88,000 miles.

This approach does not take into account possible variations in vehicle acceleration or other performance attributes. Rather, all vehicle operating characteristics are expressed in terms of two measures--battery pack capacity (for electric vehicles), and vehicle efficiency.

Even this simplified analysis requires the use of a number of assumptions:

- Battery pack capacity
- Battery cost per kWh, new and replacement
- Battery life
- Battery salvage value
- Incremental cost of EV components
- Incremental cost of HEV components
- Incremental cost of PZEV components
- Charging equipment cost
- Price of electricity
- Price of gasoline
- BEV efficiency
- HEV efficiency
- PZEV efficiency
- Maintenance cost, BEV
- Maintenance cost, HEV
- Maintenance cost, PZEV
- Inflation rate
- Discount rate

8.2. Cross-Cutting Assumptions

As noted above, a number of assumptions must be made in order to perform cost calculations. Many of these assumptions are “cross-cutting” in that they apply to all vehicles within a category (EV, HEV, or PZEV). Table 8-1 below presents the various cross-cutting assumptions, and staff’s estimate for each, for 2003 and for eventual volume production. The basis for staff’s estimates is further discussed below.

Table 8-1
Cross-Cutting Assumptions

Assumption	**2003**	**Volume Production**
NiMH battery initial cost		
Module cost	$300 per kWh	$235 per kWh
Added cost for pack	$40 per kWh	$20 per kWh
Multiplier for indirect cost	1.15	1.15
Cost as installed in vehicle	$391 per kWh	$293 per kWh
NiMH battery life [a, b]	6 years	10 years
NiMH battery salvage value	$40 per kWh	$40 per kWh
NiMH battery replacement cost		
Module cost	$267 per kWh	Not Applicable
Added cost for pack	$30 per kWh	Not Applicable
Multiplier for indirect cost	1.15	Not Applicable
Uninstalled cost	$342 per kWh	Not Applicable
Handling and installation	$500 per pack	Not Applicable
PbA battery initial cost		
Module cost	$135 per kWh	$100 per kWh
Added cost for pack	$40 per kWh	$20 per kWh
Multiplier for indirect cost	1.15	1.15
Cost as installed in vehicle	$201 per kWh	$138 per kWh
PbA battery life [a, b]	3 years	5 years
PbA battery salvage value	$3 per kWh	$3 per kWh
PbA battery replacement cost	$	
Module cost	$118 per kWh	$100 per kWh
Added cost for pack	$30 per kWh	$20 per kWh
Multiplier for indirect cost	1.15	1.15
Uninstalled cost	$170 per kWh	$138 per kWh
Handling and installation	$500 per pack	$500 per pack
Vehicle Incremental Cost		
2 passenger freeway BEV	$9,500	$1,500
4 passenger freeway BEV/pickup	$8,000	$0
City EV	$5,000	$0
HEV	$2,500	$500
PZEV	$500	$500
Charging equipment, installed	$1,500	$750
Price of electricity [c]	$0.05 per kWh	$0.05 per kWh
Price of gasoline [d]	$1.26 per gallon	$1.26 per gallon
Maintenance cost		
Freeway capable EV	$0.04 per mile	$0.04 per mile
City EV	$0.035 per mile	$0.035 per mile
HEV	$0.075 per mile	$0.075 per mile
ICE	$0.06 per mile	$0.06 per mile
Inflation rate	3 percent	3 percent
Discount rate	8 percent	8 percent

a. For 2003 vehicles, an alternative scenario is also calculated that assumes extended battery life.
b. HEV batteries are assumed to last the life of the vehicle in all cases.
c. Excludes tax. For comparison purposes, an alternative scenario is also calculated using $0.075 per kWh, to take into account the effect of daytime charging.
d. Excludes tax; equivalent to $1.75 per gallon retail. For comparison purposes, an alternative scenario is also calculated using the after-tax gasoline price of $1.75.

Battery Initial Cost

In this analysis, the battery initial cost represents the cost of the battery pack as installed in the vehicle. Several parties stated in public comments that an additional cost factor should be added to the cost of the battery as paid by the automaker to the battery manufacturer, in order to account for shipping and manufacturer indirect costs. This comment has been adopted. Thus the battery initial cost used here is the sum of three components: (1) the per module price charged by the battery manufacturer, (2) the cost of assembling modules into a battery pack, and (3) a markup factor to capture additional costs to the vehicle manufacturer. Each is discussed in turn.

Per module battery cost is taken from the draft Final Report of the Year 2000 Battery Technical Advisory Panel, and further discussion with Panel members. For NiMH batteries, the Panel reports projected cost for 2003 volume (20,000 packs per year) of $300 per kWh, and projected cost in volume production (100,000 packs per year) of $225-250 per kWh. Staff uses a midrange estimate of $235. For PbA batteries, the panel provides a range of $100 to $150 per kWh at MOA volume levels. No estimated is provided for production volume greater than 25,000 packs per year. Staff assumes $135 per kWh for year 2003 and $100 per kWh for volume production.

Pack cost also is taken from the Battery Technical Advisory Panel report. As described by the Panel, an EV battery pack consists of a number of modules connected together to provide the desired system voltage and energy storage capacity. The pack will also have a thermal management system, as well as electrical and electronic controls to regulate charge and discharge, assure safety, and prevent electrical abuse. The Panel makes a rough estimate that the cost of assembling battery modules into a complete pack is at least $1200 per pack ($40 per kWh) at 2003 volume and about half of that at volume production levels. Staff uses a fixed additional cost (not adjusted for pack size) of $40 per kWh for 2003, and $30 per kWh for replacement packs, and $20 per kWh for volume production.

A markup factor is needed to account for overhead, dealer support, and other costs that are added to manufacturing costs as part of the cost structure for vehicle production. Specific cost structure information is proprietary and difficult to obtain. The Delucchi and the Cuenca cost reports referenced above each have a discussion of possible cost factors. Staff has adopted the cost factor used in the Cuenca report. The base case analysis in that report uses a 1.15 multiplier, described as “optimistic”, that accounts only for marketing cost and profit. This approach is described as similar to that used in aircraft assembly or heavy duty truck manufacturer, in which expensive engines procured from outside suppliers are used with a relatively low markup. The report also provides results for an alternative scenario, using a 1.3 multiplier that accounts for dealer support, distribution, marketing, a small part of corporate overhead, and profit. Staff follows the Cuenca analysis and uses a 1.15 multiplier, but recognizes that this represents an optimistic scenario.

To illustrate how these three components are combined, the $391 per kWh cost estimated for 2003 NiMH batteries is arrived at by first adding together (1) a $300 per kWh cost at the module level, plus (2) a $40 per kWh cost for assembly into a pack. This total, $340 per kWh, is then multiplied by (3) the markup factor of 1.15, to arrive at the total of $391 per kWh as shown in Table 8-1.

<u>Battery Pack Life</u>

Battery life has a significant effect on lifecycle cost. Staff’s assessment of battery pack life is based on the work of the Battery Technical Advisory Panel, and on comments provided by battery manufacturers and other parties.

For 2003, staff assumes that battery pack life for PbA batteries is 3 years, and for NiMH batteries is 6 years. Although not yet fully demonstrated in real world driving, this level of durability appears to be well within the reach of the most recent battery technologies.

Data exists which suggests that longer battery lives are possible. For example, the Battery Technical Advisory Panel reported that “bench tests and recent technology improvements in charging efficiency and cycle life at elevated temperature indicate that NiMH batteries have realistic potential to last the life of an EV, or at least ten years and 100,000 vehicle miles”. Bench test data for the Panasonic PbA batteries installed in the GM EV1 indicate that the battery maintains more than 80 percent of its capacity for more than 1000 cycles, equivalent to more than 50,000 miles. Because real world data is not available to demonstrate this performance with the reliability needed for large scale introduction in motor vehicles, staff is reluctant to assume such levels for 2003. To provide a complete picture of possible outcomes, however, we also provide an alternative cost analysis for 2003 that assumes a 5 year life for PbA batteries and a 10 year life for NiMH batteries. We also assume 5 and 10 year lifetimes for batteries used in future volume production.

Because the assumed life of the vehicle is 10 years, when replacement packs are needed some allowance must be made to account for unused battery life at the end of the 10 year period. For example, if battery life is 6 years and a new pack is installed in year 7, at the end of year 10 the pack still has 2 years of useful life. In such instances we increase the "salvage value" in year 10 to account for the remaining battery life. For example, if the cost of a 6 year NiMH battery pack is $13,260, and at the end of year 10 the pack has two years of useful life remaining, we add one-third of the battery pack cost, or $4,420, to the salvage value of the battery in year 10.

Manufacturers noted in public comment that the assumption of linear depreciation was too optimistic in that vehicles lose much of their value in the first few years. Staff believes that the value of the battery pack is based strictly on its capacity, and therefore has retained the original method.

Battery Pack Salvage Value

Staff assumes that the salvage value for EV batteries will be $40 per kWh for NiMH batteries and $3 per kWh for lead acid batteries. This amount, which accounts for the value of the battery for secondary uses (NiMH) or material recycling (PbA), is in addition to any credit for remaining battery life as discussed above.

Batteries for electric vehicles generally are considered to have reached the end of their useful life when their capacity has dropped by 20 percent. Staff notes that for NiMH batteries, even a 30 percent reduction in capacity would still allow vehicles to have adequate range for many applications.

However "useful life" is defined, it is clear that a somewhat depleted NiMH EV battery still has significant capacity available for use in less-demanding applications. Battery manufacturers and utility companies are investigating possible secondary markets for used vehicle batteries, which generally involve supplying power in remote or distributed locations where the long life of advanced batteries could provide a significant maintenance cost advantage. A secondary market that provides a salvage value for vehicle batteries will effectively reduce the battery cost. EPRI has work underway to better estimate the value of NiMH secondary uses. Their results are not yet available. In the absence of more specific information, staff assumes $40 per kWh.

The existence of a secondary market for PbA batteries at meaningful volume levels is in staff's view more speculative. The $3 estimate for PbA represents the value of the materials in the battery.

Battery Replacement Cost

Two opposing factors affect battery replacement cost. First, due to technical improvement and increased volume, it is likely that in the early years of production the module cost of a replacement pack will be less than the module cost of the pack it replaces. On the other hand, due to the cost of distribution, dealer support and on-site installation, the actual installed cost of a replacement battery pack will be more than the cost of a battery pack installed at the factory.

In our calculations, we assume that for 2003 vehicles the uninstalled cost of the replacement pack is halfway between the 2003 cost and the "volume production" cost. (For volume production vehicles we assume that the per module cost is the same for the original pack as for the replacement pack.) We also assume that handling and installation total $500 per pack, which covers shipping, storage, testing, and installation of the replacement pack. For example, for a 2003 NiMH vehicle, the uninstalled cost of a replacement pack is $342 per kWh, halfway between the $391 per kWh cost of the original pack and the $293 per kWh cost of the pack in volume production. The cost of the replacement pack is then increased by $500 to give the installed cost.

Vehicle Incremental Cost

Freeway Battery Electric Vehicles. The incremental cost of the vehicle means the cost of an EV, minus the battery, as compared to the cost of a baseline SULEV ICE vehicle. Please note that in the preliminary draft Staff Report the baseline comparison vehicle was a PZEV rather than a SULEV. This was changed in response to public comment.

The incremental cost is highly dependent on production volume. Although staff provides estimates for both low and high volume production, for purposes of cost comparison to other vehicle types it is appropriate to use the long-term, learned out cost in volume production.

Staff has developed two estimates of incremental cost for each production level—one for the 4 passenger vehicles, and a higher estimate for the highly efficient 2 passenger commuter vehices. The latter are modeled after the EV1 and make use of lightweight components.

In order to estimate incremental costs, staff reviewed the cost analyses prepared by Cuenca et al and by Delucchi. For low volume production (roughly equivalent to 2003 levels) Cuenca provides estimates for several different manufacturing methods (based on existing vehicle, based on new design, assembled from glider, conversion from a conventional vehicle). These estimates range from $1,300 for glider assembly to $4,300 for an EV based on a new design. These estimates do not, however, include any volume-related additional cost for the drivetrain. Rather, the authors assume aggregate demand would be sufficient to have high volume production levels and costs for the EV drivetrain.

Delucchi provided ARB staff with unpublished model runs that calculate an incremental cost for low volume production of roughly $8,000 to $14,000 depending on the vehicle characteristics. Confidential information from vehicle manufacturers shows higher estimated costs.

Staff assumes $8,000 for the 4 passenger vehicles, at the low end of the Delucchi range and close to the low end of the manufacturer information.

For high volume production both the Delucchi and the Cuenca studies conclude that the vehicle minus the battery will cost roughly the same as the equivalent ICE vehicle. In our site visits, auto manufacturers generally maintained that due to the need for additional components (e.g. electric power steering, electric heating and air conditioning, regenerative brakes) the non-battery portion of an electric vehicle was likely to always have some cost premium. Several manufacturers also stated, however, that in volume production such a premium would be small relative to the extra cost of the battery. Staff assumes no additional cost in volume production for the 4 passenger battery electric vehicles, excluding the cost of the battery.

For the 2 passenger vehicles, which are assumed to make extensive use of aluminum, staff uses an added cost of $1,500 for both 2003 and for volume production. This estimate, which should be considered an approximation, is based on work by the Office of Technology Assessment. In their report <u>Advanced Automotive Technology</u> that Office estimated that the additional cost in 2005 for a first generation aluminum vehicle would be on the order of $1,200 to $1,500 per vehicle, with about $800 in materials cost and the balance in handling and manufacturing cost.

<u>City Electric Vehicles</u>. The incremental cost for a city EV, minus the battery, is assumed to be $5,000 at 2003 production levels and $0 in large volume. Staff is not aware of published estimates that focus on City EV manufacturing cost. In the absence of more specific information, we assume 2003 incremental cost slightly lower than that for freeway capable EVs. Large volume production incremental cost is treated the same as for freeway capable EVs.

<u>Hybrid Electric Vehicles</u>. The incremental cost of HEV components, excluding the battery pack, is assumed to be $2,500 in 2003 and $500 in volume production. This results in a total incremental cost, including the battery pack, of about $3,300 in 2003 and $1,100 in volume production. The 2003 level corresponds to manufacturer published announcements regarding desired incentive levels to encourage the purchase of HEVs. A modest cost premium is assumed even or volume production because a hybrid electric vehicle needs all of the components of an ICE vehicle, plus components unique to a hybrid.

PZEV Vehicles. Staff assumes an incremental cost for PZEVs of $500 in 2003 and in volume production, which is in the middle of the range estimated by staff during the LEV II rulemaking. In the LEV II staff analysis, the incremental cost to the consumer of a conventional gasoline vehicle that qualifies to receive 0.2 partial ZEV credit (e.g. Nissan Sentra CA) relative to a gasoline SULEV vehicle was estimated to be in the range of $385 to $800. Staff estimated that PZEV vehicles would incur additional costs in the following three categories compared to a SULEV:

a) Additional emission control hardware such as a HC adsorber or additional catalyst loading may be required in larger six-cylinder or difficult to control four-cylinder engines to ensure continued compliance with emission standards for 150,000 miles vs. 120,000 miles.

b) All PZEV gasoline vehicles are required to be equipped with fuel systems certified to the zero-fuel evaporative emission standards for 150,000 miles. The use of advanced fuel/evaporative systems that are capable of eliminating fuel evaporative emissions would be required for compliance with the zero-fuel evaporative standards. Some of these systems include a sealed fuel system, a pressurized fuel system and upgraded joint hardware and lines. The costs of such systems have been estimated to be in the range of $50 to $150.

c) For PZEV vehicles, all emission-related malfunctions detected by the vehicle's OBD II system must fixed under warranty up to 15-years/150,000 miles, whichever occurs first. This requirement is significantly more stringent than the 3-year or 50,000 mile (7-years/70,000 miles for high cost components) emission warranty requirement applicable to SULEVs. As a result, staff believes that virtually every PZEV gasoline vehicle would require some amount of warranty work over its useful life. Accordingly, staff estimated the increased warranty costs to be between $300 to $500 per vehicle.

An additional ten- percent was added to these costs to account for cost of capital recovery, dealership costs and other miscellaneous costs.

Charging Equipment Cost

The cost estimation methodology outlined in the Preliminary Draft staff report did not include the cost of electric vehicle charging equipment. Public comment has pointed out that the cost of a charger should be included, and staff agrees. Staff has reviewed several published estimates of the equipment and installation cost for the off-board portion of vehicle charging equipment. (The cost of the on-board components is included in the estimate of vehicle incremental cost). Delucchi estimates near-term cost of $1,200 for a dedicated high power circuit plus the off board charger, and long-term cost of $400. The long-term cost assumes the use of an integrated conductive charger at a cost of $250, and $150 on average for installation of the dedicated circuit. Cuenca estimates a lifecycle added cost of $0.005 to $0.01 per mile initially, and half that at high production volume. Using our cost estimation methodology, $0.01 per mile lifecycle cost is the equivalent of $1,200 in initial cost. In addition to these published estimates, automaker comments stated that chargers can cost $1,500 or more, not including installation.

Staff assumes 2003 cost for charging equipment will average $1,500, including installation. This assumes minor improvement in both component and installation cost over current levels, and is in the same range as the Delucchi and Cuenca estimates. Staff assumes volume production cost of $750, based on the Delucchi estimate but increased to allow for higher average installation costs.

Price of Electricity

Staff assumes that the price of electricity for EV charging will be $0.05 per kWh, which assumes 90 percent off-peak charging. To allow consideration of other scenarios, under which a lower proportion of charging may occur off-peak due to daytime use of convenience chargers, or workplace charging, we also present an alternative case using an average electricity price of $0.075 per kWh.

Electric vehicles that charge with off-peak power have a fuel cost advantage over gasoline fueled vehicles. Off-peak electricity is cheaper than gasoline from an energy content standpoint, and electric vehicles use their energy very efficiently. The size of the fuel cost differential between electric and gasoline vehicles will vary according to the relative fuel prices.

The electricity prices used in this analysis exclude taxes. Taxes are likewise excluded from gasoline prices. This approach is taken because taxes on electricity and gasoline are “transfer payments” used for other social purposes and are not truly a part of the cost of the product. (In economic terms, transfer payments are transfers of money or economic value from one party to another without an exchange of goods or services in return, and are not included within costs or benefits.) In Sacramento, which staff believes is representative of the rest of the state, electricity is assessed a 7.5 percent local use tax plus a 2 mil per kWh state surcharge.

Price of Gasoline

Staff assumes a gasoline price of $1.26 per gallon, which excludes taxes. As noted above, a similar approach is taken with respect to electricity prices. Federal and state fuel excise taxes currently total $0.363 per gallon. In addition, a sales tax of between 7.25 percent and 8.25 percent is assessed on the total cost of the sale. At current gasoline prices of about $1.75 per gallon, tax included, these taxes account for about $0.49 of the $1.75.

Because hybrid electric vehicles are more efficient than conventional ICE vehicles, they will have a fuel cost advantage over gasoline fueled vehicles. The size of the cost advantage will vary according to the price of gasoline.

Consumers, of course, pay fuel prices that include tax. Thus in assessing the cost faced by a driver and its effect on a purchase or lease decision, the full price with tax included should be used. The base case staff calculations assume prices without tax but staff provides alternative calculations that include tax.

Maintenance Cost

Maintenance costs are assumed to be as follows:

Freeway Capable Battery EV	$0.04
City EV	$0.035
HEV	$0.075
ICE	$0.06

The Automobile Club of Southern California publishes estimates of driving cost based on regional data. These costs have been calculated by averaging the owning and operating expenses of three 1999 car makes--the Chevrolet Cavalier LS, the Ford Taurus SE, and the Mercury Grand Marquis LS. For these 1999 vehicles the club estimates maintenance expenses of $0.04 per mile and tire expenses of $0.017 per mile. Staff rounds the total to $0.06 per mile and uses this figure as the estimate for conventional internal combustion engine vehicles.

Due to the different technologies employed, maintenance costs for electric vehicles may differ from those for gasoline vehicles. Several of the studies discussed in Section 8.1.1 above have attempted to estimate electric vehicle maintenance costs. Staff has also received public comment regarding maintenance costs experienced by utility company EV fleets. Based on the available information, in this analysis staff assumes that EV maintenance costs will be about $0.04 per mile, roughly one-third less than ICE maintenance costs. This estimate takes into account the fact that EV tires, which are optimized for low rolling resistance, are more expensive.

City EV maintenance cost is assumed to be $0.035 per mile, somewhat less than for freeway capable EVs. This reduction is due to the smaller size and weight of the vehicles.

Maintenance costs for hybrid electric vehicles may differ from those for gasoline or battery electric vehicles. Because hybrid vehicles employ both a conventional and an electric drive system, staff assumes that maintenance cost for hybrids will be higher than for gasoline or electric vehicles. In the absence of more specific information staff assumes that hybrid electric vehicle maintenance costs will be 25 percent higher than for ICE vehicles, or $0.075 per mile.

Inflation Rate

Annual inflation is assumed to be 3 percent. Ongoing costs such as maintenance and fuel can be expected to increase over time with inflation. Staff is not aware of information that would justify assigning separate inflation rates to the different categories. Therefore a single rate is assumed to apply to all future costs, other than battery pack replacement and battery pack salvage value. Because staff expects battery costs to decline over time, these costs are not inflated.

Discount Rate

The assumed discount rate is 8 percent. The rationale for using a discount rate when considering the value of future costs and benefits is discussed in A Guide for Reviewing Environmental Policy Studies—A Handbook for the California Environmental Protection Agency (M Cubed, 1994). This report notes that "A discount rate is used to calculate the present discounted value of future benefits and costs….The farther in the future benefits are received, the less value they have compared to receiving the same benefits today. The discount rate reflects the time value of money and the risk associated with future benefits and costs."

The higher the discount rate, the lower the value, in today's dollars, of costs or payments which occur in future years. Battery electric vehicles typically will have higher initial costs, offset by fuel cost savings over a period of years. Therefore the discount rate used will affect their lifecycle cost relative to internal combustion vehicles, which have lower initial costs but higher fuel costs over time.

The Cal/EPA guidelines for economic analysis recommend that the discount rate used in an analysis should equal "the interest rate on United States Treasury Securities with a maturity that most closely approximates the project [time] horizon, plus two percent." In this instance, the time horizon of the cost analysis is ten years. Therefore according to the Cal/EPA guidelines the resulting discount rate should equal the current interest rate on 10-year Treasury Securities (around 6 percent) plus 2 percent, or 8 percent total.

The discount rates used here are assumed to include inflation. In other words, a nominal discount rate of 8 percent, as used here, equates to a "real" discount rate of 5 percent given the assumed inflation rate of 3 percent.

Value of EV Connection to Utility

At the May workshop one commenter suggested that EV battery packs could provide distributed energy services to electric utilities. In this scenario, a computer controlled bi-directional power interface would allow power to be stored in or withdrawn from EV battery packs as needed, given time-of-day system capacity and demand. EV battery packs could be used to provide peak power, reactive power, or spinning reserves to the utility. Initial calculations estimate that the value of such an arrangement could be possibly $10 per month per kWh of battery capacity, with a net present value reported at $125 to $565 per kWh. Building on such distributed energy arrangements, researchers have presented long term visions of an electricity supply system without central generators, with generation provided exclusively by customer owned fuel cell EVs. Alternatively or in combination, the electric supply system could use a high proportion of intermittent renewable energy sources, buffered by distributed storage in the battery EV fleet.

Staff recognizes the potential value of such distributed energy services. The real-world practicality of such mechanisms must be further assessed, however, and staff has not assigned any dollar value to distributed energy services in its cost calculation methodology.

8.3 Assumptions--Freeway Capable Battery Electric Vehicles

This section presents the vehicle-specific assumptions used to derive cost estimates for freeway capable battery electric vehicles. Several different vehicle types are considered. In this context the range figures provided represent real-world driving range. Cost estimates are developed for both NiMH and PbA versions of most these vehicles.

The specific attributes of each vehicle type are listed in Table 8-2 and discussed in more detail below.

Table 8-2
Vehicle-Specific Assumptions
Freeway Capable Battery Electric Vehicles

Vehicle Type	Battery Type	Pack Capacity (kWh)	Vehicle Efficiency (kWh/mile)	Range (miles)[b]
2003				
MOA 2 passenger	NiMH	33.4	.373	145
MOA 2 passenger	PbA	19.1	.248	81
MOA 4 passenger	NiMH	31.5	.476	73
MOA 4 passenger	PbA	17.6	.438	40
MOA fleet/pickup	NiMH	32.0	.539	64
MOA fleet/pickup	PbA	19.1	.511	37
Volume production				
MOA 4 passenger	NiMH	31.5	.380	90
HE[c] 2 passenger, 60 mile	NiMH	10.2	.187	60
HE 2 passenger, 60 mile	PbA	10.5	.177	60
HE 2 passenger, 100 mile	NiMH	17.4	.191	100
HE 2 passenger, 100 mile	PbA	18.5	.186	100
HE 2 passenger, 150 mile	NiMH	28.8	.198	150
HE 4 passenger, 60 mile	NiMH	14.8	.271	60
HE 4 passenger, 60 mile	PbA	15.2	.256	60
HE 4 passenger, 100 mile	NiMH	25.2	.277	100
HE 4 passenger, 100 mile	NiMH	22.5	.249	100

a. Total of vehicle incremental cost, initial battery pack, and charging equipment.
b. Real-world driving range.
c. High efficiency.

Vehicle Efficiency and Battery Pack Capacity

Estimates were determined by calculating vehicle performance under steady-state (freeway) driving conditions at 70 mph. Unlike conventional non-hybrid gasoline automobiles, EVs demonstrate improved efficiency when operated under low-speed urban driving cycles and are less efficient when operated at high speeds. Real life estimates of current and projected EV performance should therefore be based on conditions that are challenging to EVs and that best agree with MOA-era real life EV experience.

The 2003 vehicles are assumed to be identical in efficiency to the MOA vehicles that have been placed as part of the demonstration program. Efficiency ratings are based upon EV America and SCE test results. The lower efficiency shown for NiMH vehicles as compared to PbA is due to their reduced charging efficiency at high temperatures and the energy needed for battery thermal management.

The “base case” volume production 4 passenger EV, which we describe as “MOA 4 passenger”, is a MOA type vehicle with minor efficiency improvements over today’s technology. The assumed efficiency is taken from the A.D. Little work on full fuel cycle vehicle energy efficiency. Staff is confident that this efficiency level would be achieved in vehicles brought to market in the volume production timeframe.

Staff also provides cost estimates for several configurations of “high efficiency” volume production EVs. These examples are provided in order to illustrate the effect of efficiency improvement on vehicle initial cost and lifecycle cost. Increased efficiency allows the use of a smaller battery pack. For example, the most efficient 100 mile 4 passenger volume production NiMH vehicle assumes a pack size of 22.5 kWh, as compared to 31.5 kWh for the MOA type volume production vehicle. Use of a smaller pack reduces both initial cost and lifecycle cost.

The high efficiency vehicles are assumed to be 2nd or 3rd generation versions of OEM ZEVs with improvements over MOA-era vehicles in several of their efficiency-related attributes. These improvements include aerodynamic drag reduction, lower loss tires, higher efficiency drive systems, and substantial improvements in charging efficiency. More specifically, the 2-seat commuter vehicles incorporate an 88 percent efficient drive system (roughly 10 percent more efficient than that used in MOA vehicles), a considerable improvement in charging efficiency (from 46 percent to 73 percent), but no aerodynamic improvements. The 4 passenger vehicles incorporate all of these commuter improvements, and also assume a design with substantial aerodynamic drag reduction resulting in a drag coefficient of 0.2.

The final 4 passenger volume production vehicle is a sedan that takes advantage of all of the 4 passenger vehicle improvements noted above, but in a smaller vehicle with a frontal area of only 2.07 square meters.

Staff notes that these hypothetical vehicles do not assume efficiency improvements as radical as those demonstrated on actual state-of-the-art prototype ZEVs and HEVs. Chassis mass reductions requiring composite materials were not incorporated, and battery specific energy was assumed to remain at 35 whr/kg for PbA batteries and 70 whr/kg for NiMH. Reductions in battery pack mass to obtain commuter EVs were considered without corresponding reductions in chassis structural mass. It may be desirable to offer a platform with multiple battery pack versions where a short-range, 60 mile (real-life) EV would be burdened with an over-designed chassis, but could be made less expensive by sharing components and development costs with its longer-range versions.

Cost of Sales.

In public comments, an automaker stated that EVs have a higher "cost of sales" due to additional time demands on dealership staff, and suggested that staff's cost model specifically account for this cost. Staff recognizes that EVs do require additional effort from sales staff. Because our cost model is primarily focused on hardware cost, however, staff has not adopted this suggestion.

8.4 Assumptions--City Electric Vehicles

This section presents the vehicle-specific assumptions used to derive cost estimates for City electric vehicles. Staff develops calculations for NiMH and PbA versions for 2003 and for volume production. Again the range estimates shown are for real-world driving.

The specific attributes of each vehicle type are listed in Table 8-3 and discussed in more detail below.

Table 8-3
Vehicle-Specific Assumptions
City Electric Vehicles

Vehicle Type	Battery Type	Pack Capacity (kWh)	Vehicle Efficiency (kWh/mile)	Range (miles)[a]
2003				
City EV	NiMH	9.1	.250	36
City EV	PbA	5.3	.250	21
Volume production				
City EV	NiMH	9.1	.180	50
City EV	PbA	5.3	.180	29

a. Real world driving range.

Please note that in the City EV lifecycle cost calculations the lifetime vehicle miles traveled is assumed to be 75 percent of that for the other vehicles, or about 88,000 miles over ten years.

Vehicle Efficiency and Battery Pack Capacity

Vehicle efficiency and battery pack capacity estimates for 2003 are based on published specifications of existing city EVs. Modest efficiency improvement is assumed for future volume production vehicles.

8.5 Low Speed Vehicles

Low speed vehicles are on the market today, at prices of around $7,000. These prices appear to cover the cost of production plus manufacturer profit. Because these vehicles are aimed at entirely different market niches from the other battery electric and PZEV vehicles, there is no need to calculate how their lifecycle cost compares. Therefore staff has not developed cost comparison ranges for low speed vehicles.

8.6 Assumptions--Power Assist Hybrid Electric Vehicles

This section presents the vehicle-specific assumptions used to derive cost estimates for power assist hybrid electric vehicles. Several different vehicle types are considered, which are intended to be comparable to the freeway capable electric vehicles discussed above. The specific attributes of each vehicle type are listed in Table 8-4 and discussed in more detail below.

Table 8-4
Vehicle-Specific Assumptions
Power Assist Hybrid Electric Vehicles

Vehicle Type	Battery Type	Pack Capacity (kWh)	Vehicle Efficiency (miles/gallon)
2003			
2 passenger	NiMH	2.0	70
4 passenger	NiMH	2.0	45
Fleet/pickup	NiMH	2.0	30
Volume production			
2 passenger	NiMH	2.0	80
4 passenger	NiMH	2.0	55
Fleet/pickup	NiMH	2.0	35

<u>Vehicle Efficiency</u>.

Vehicle efficiency for 2003 passenger HEVs is based upon published mile per gallon figures for currently available hybrids. The fleet/pickup mileage is based upon an assumed 25 percent improvement over the gasoline version. Modest further improvements are assumed for volume production.

8.7 Assumptions--Internal Combustion Engine Vehicles

This section presents the vehicle-specific assumptions used to derive cost estimates for internal combustion engine Partial Zero Emission Vehicles (PZEVs). Once again the vehicles considered are intended to be comparable to the freeway capable electric vehicles discussed above. The specific attributes of each vehicle type are listed in Table 8-5 and discussed in more detail below.

Table 8-5
Vehicle-Specific Assumptions
PZEV Vehicles

Vehicle Type	Vehicle Efficiency (miles/gallon)
2003	
2 passenger	40
4 passenger	30
Fleet/pickup	20
Volume production	
2 passenger	45
4 passenger	35
Fleet/pickup	25

<u>Vehicle Efficiency</u>.

Vehicle efficiency for 2003 is based upon current mileage for subcompact, compact and pickup vehicles. Again a modest improvement is assumed for future production.

8.8 Cost Calculations

This section presents the results of staff calculations using the assumptions outlined above. Cost estimates are first presented for 2003, then for future volume production. The 2003 estimate assumes volume of roughly 20,000 to 30,000 vehicles per year. In public comment manufacturers have noted that because each individual manufacturer will produce only a portion of the statewide total, their costs will be based on smaller production runs. Other commenters have noted, however, that vehicles will be produced for other states and countries as well as for California, and that the aggregate demand will be higher than the California-only figure. Taking into account both factors, staff continues to use assumed volume of 20,000 to 30,000. Staff agrees that if the actual number of vehicles produced in 2003 is significantly less than this number, due to early introduction or other factors, battery cost and the overall cost per vehicle will increase.

Within each time period, similar vehicles are presented together (2 passenger, 4 passenger, pickup/fleet).

For each vehicle type we present the following:

<u>Incremental initial cost</u>, which includes the incremental cost for that vehicle as compared to the baseline SULEV vehicle, plus, where necessary, the cost of the initial battery pack and charging equipment.

Incremental lifecycle cost per mile, which is the present discounted value, per mile, of the sum of incremental initial cost plus operating cost over the life of the vehicle.

A discussion of the various results is provided in Section 8.9 after all results have been tabulated.

8.8.1 Cost Estimates for 2003

This section presents cost calculations for 2003, first for the base case and then for the alternative scenarios.

Base Case.

Results for the base case are shown in Table 8-6 below. The base case assumes battery life of 6 years for NiMH and 3 years for PbA, and a pre-tax gasoline price of $1.26 per gallon. Alternative scenarios follow, which assume longer battery life, increased gasoline prices, and increased electricity prices.

Please note that the various battery electric vehicles shown have different range and therefore are not directly comparable. (The assumed range for each vehicle is noted under Vehicle Specific Assumptions above). Later on we show the results of an equal-mileage comparison between NiMH and PbA vehicles.

A printout of the complete calculation for Vehicle 1 (MOA 2 passenger NiMH vehicle) follows Table 8-6.

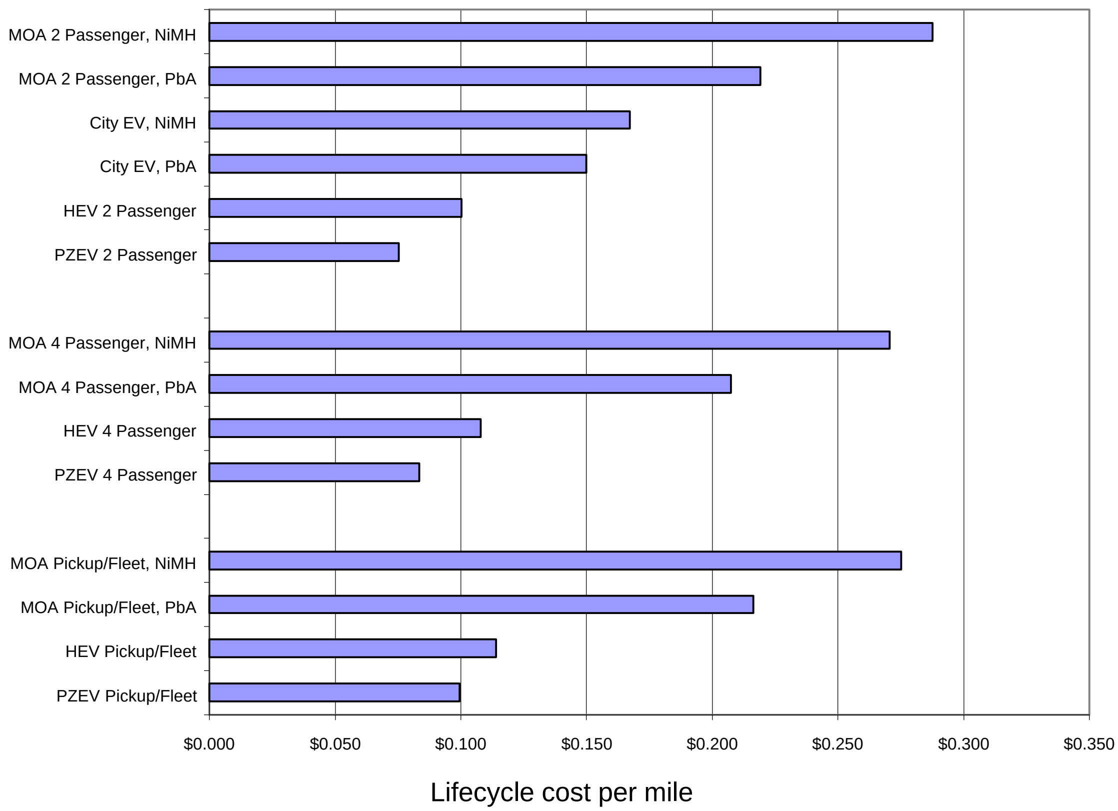
Table 8-6
2003 Vehicles
Base Case Cost Estimates

Vehicle Type	Battery Type	Charger Cost	Initial Pack Cost	Vehicle Incremental Cost	Total Incremental Cost	Lifecycle Cost per Mile
2 Passenger						
MOA 2 Passenger	NiMH	$1,500	$13,059	$9,500	$24,059	$0.288
MOA 2 Passenger	PbA	$1,500	$3,839	$9,500	$14,839	$0.219
City EV	NiMH	$1,500	$3,558	$5,000	$10,058	$0.167
City EV	PbA	$1,500	$1,065	$5,000	$7,565	$0.150
HEV 2 Passenger	NiMH	$0	$782	$2,500	$3,282	$0.100
PZEV 2 Passenger	NA	$0	$0	$500	$500	$0.075
4 Passenger						
MOA 4 Passenger	NiMH	$1,500	$12,317	$8,000	$21,817	$0.270
MOA 4 Passenger	PbA	$1,500	$3,538	$8,000	$13,038	$0.208
HEV 4 Passenger	NiMH	$0	$782	$2,500	$3,282	$0.108
PZEV 4 Passenger	NA	$0	$0	$500	$500	$0.083
Pickup/fleet						
MOA Pickup/Fleet	NiMH	$1,500	$12,512	$8,000	$22,012	$0.275
MOA Pickup/Fleet	PbA	$1,500	$3,839	$8,000	$13,339	$0.216
HEV Pickup/Fleet	NiMH	$0	$782	$2,500	$3,282	$0.114
PZEV Pickup/Fleet	NA	$0	$0	$500	$500	$0.099

Present Value Calculation--Vehicle 1							
Discount rate:			8%				
Battery cost, $ per kWh:			$391				
Pack capacity, kWh:			33.4				
Initial pack cost:			$13,059				
Pack life, years:			6				
Replacement pack cost, $ per kWh:			$342				
Replacement pack cost, uninstalled			$11,423				
Replacement pack handling/install			$500				
Replacement pack cost, installed:			$11,923				
Pack salvage value, $ per kWh:			$40				
Pack salvage value, total:			$1,336				
Replacement pack cost, minus salvage:			$10,587				
Electricity cost, $ per kWh:			$0.05				
EV component & charger cost:			$11,000				
kWh per mile:			0.373				
Maintenance, $ per mile:			$0.040				
Inflation rate:			1.03				
			Components				
Year	Mileage	Pack Cost	& charger	Elect. Price	Fuel	Maintenance	Total
0	0	$13,059	$11,000				$24,059
1	13,352	$0	$0	$0.050	$249	$534	$783
2	12,948	$0	$0	$0.052	$249	$533	$782
3	12,556	$0	$0	$0.053	$248	$533	$781
4	12,176	$0	$0	$0.055	$248	$532	$780
5	11,808	$0	$0	$0.056	$248	$532	$779
6	11,450	$10,587	$0	$0.058	$248	$531	$11,365
7	11,104	$0	$0	$0.060	$247	$530	$778
8	10,768	$0	$0	$0.061	$247	$530	$777
9	10,442	$0	$0	$0.063	$247	$529	$776
10	10,126	-$5,144	$0	$0.065	$246	$528	-$4,369
Total	116,730	$18,503	$11,000		$2,477	$5,313	$37,292
NPV of total		$17,348	$11,000		$1,663	$3,568	$33,579
$ per mile		$0.149	$0.094		$0.014	$0.031	$0.288

Graph 8-1 on the next page shows incremental lifecycle cost per mile for the various vehicles.

Graph 8-1
2003 Vehicles
Estimated Incremental Lifecycle Cost per Mile



<u>Alternative Scenarios</u>.

Next we present the results of three alternative scenario, which assume (1) longer battery life (10 year for NiMH and 5 years for PbA), (2) higher gasoline prices (using the nominal gasoline price of $1.75 per gallon rather than the pre-tax price of $1.26 per gallon), and(3) higher electricity prices ($0.075 per kWh average rather than $0.05 per kWh). Tables 8-7, 8-8 and 8-9 present the results for these scenarios.

As is shown in the tables, the increased battery life decreases the lifecycle cost for the freeway capable battery electric vehicles by about 15 percent. The City EVs show a smaller change due to the relatively smaller size of their battery pack. The increased cost of gasoline increases the lifecycle cost of the HEVs by some 5 to 9 percent, and increases lifecycle cost for the PZEVs by about 12 to 19 percent. The impact on HEVs is less due to their greater fuel economy. Increased electricity prices have only a minor effect, increasing lifecycle cost by about 2 to 5 percent.

Table 8-7
2003 Vehicles
Alternative Scenario Cost Estimates
(Increased Battery Life)

	Incremental Lifecycle Cost Per Mile			
Vehicle Type	**Base Case**	**Increased Battery Life**	**Difference**	**Percent**
2 Passenger				
MOA 2 Passenger, NiMH	$0.288	$0.246	-$0.042	-14.6%
MOA 2 Passenger, PbA	$0.219	$0.188	-$0.031	-14.0%
City EV, NiMH	$0.167	$0.149	-$0.018	-10.7%
City EV, PbA	$0.150	$0.133	-$0.016	-11.0%
HEV 2 Passenger	$0.100	$0.100	$0.000	0.0%
PZEV 2 Passenger	$0.075	$0.075	$0.000	0.0%
4 Passenger				
MOA 4 Passenger, NiMH	$0.270	$0.231	-$0.040	-14.7%
MOA 4 Passenger, PbA	$0.208	$0.179	-$0.029	-13.8%
Hybrid 4 Passenger	$0.108	$0.108	$0.000	0.0%
PZEV 4 Passenger	$0.083	$0.083	$0.000	0.0%
Pickup/fleet				
MOA Pickup/Fleet, NiMH	$0.275	$0.235	-$0.040	-14.7%
MOA Pickup/Fleet, PbA	$0.216	$0.186	-$0.031	-14.2%
Hybrid Pickup/Fleet	$0.114	$0.114	$0.000	0.0%
PZEV Pickup/Fleet	$0.099	$0.099	$0.000	0.0%

Table 8-8
2003 Vehicles
Alternative Scenario Cost Estimates
(Increased Gasoline Price)

	Incremental Lifecycle Cost Per Mile			
Vehicle Type	**Base Case**	**Increased Gas Price**	**Difference**	**Percent**
2 Passenger				
MOA 2 Passenger, NiMH	$0.288	$0.288	$0.000	0.0%
MOA 2 Passenger, PbA	$0.219	$0.219	$0.000	0.0%
City EV, NiMH	$0.167	$0.167	$0.000	0.0%
City EV, PbA	$0.150	$0.150	$0.000	0.0%
HEV 2 Passenger	$0.100	$0.106	$0.005	5.3%
PZEV 2 Passenger	$0.075	$0.085	$0.009	12.4%
4 Passenger				
MOA 4 Passenger, NiMH	$0.270	$0.270	$0.000	0.0%
MOA 4 Passenger, PbA	$0.208	$0.208	$0.000	0.0%
Hybrid 4 Passenger	$0.108	$0.116	$0.008	7.7%
PZEV 4 Passenger	$0.083	$0.096	$0.012	15.0%
Pickup/fleet				
MOA Pickup/Fleet, NiMH	$0.275	$0.275	$0.000	0.0%
MOA Pickup/Fleet, PbA	$0.216	$0.216	$0.000	0.0%
Hybrid Pickup/Fleet	$0.114	$0.125	$0.011	9.4%
PZEV Pickup/Fleet	$0.099	$0.118	$0.019	18.8%

Table 8-9
2003 Vehicles
Alternative Scenario Cost Estimates
(Increased Electricity Price)

	Incremental Lifecycle Cost Per Mile			
Vehicle Type	**Base Case**	**Increased Elect. Price**	**Difference**	**Percent**
2 Passenger				
MOA 2 Passenger, NiMH	$0.288	$0.295	$0.007	2.5%
MOA 2 Passenger, PbA	$0.219	$0.224	$0.005	2.2%
City EV, NiMH	$0.167	$0.172	$0.005	2.9%
City EV, PbA	$0.150	$0.155	$0.005	3.4%
HEV 2 Passenger	$0.100	$0.100	$0.000	0.0%
PZEV 2 Passenger	$0.075	$0.075	$0.000	0.0%
4 Passenger				
MOA 4 Passenger, NiMH	$0.270	$0.280	$0.010	3.5%
MOA 4 Passenger, PbA	$0.208	$0.216	$0.008	4.1%
Hybrid 4 Passenger	$0.108	$0.108	$0.000	0.0%
PZEV 4 Passenger	$0.083	$0.083	$0.000	0.0%
Pickup/fleet				
MOA Pickup/Fleet, NiMH	$0.275	$0.285	$0.010	3.6%
MOA Pickup/Fleet, PbA	$0.216	$0.226	$0.010	4.5%
Hybrid Pickup/Fleet	$0.114	$0.114	$0.000	0.0%
PZEV Pickup/Fleet	$0.099	$0.099	$0.000	0.0%

8.8.2 Cost Estimates for Volume Production

This section presents cost calculations for volume production, once again for a base case and for an alternative scenario. The assumptions used are detailed in Cross-Cutting Assumptions and Vehicle Specific Assumptions above.

Base Case.

Results for the base case are shown in Table 8-10 below. The base case assumes battery life of 10 years for NiMH and 5 years for PbA, a pre-tax gasoline price of $1.26 per gallon, and an electricity price of $0.05 per kWh. Alternative scenarios follow that use the after-tax gasoline price of $1.75 and an increased electricity price of $0.075.

The first results listed in the Table 8-10 are for “standard vehicles”, which include PZEVs, HEVs, and what we describe as the “MOA 4 passenger” battery electric vehicle. The latter is a MOA type vehicle with minor efficiency improvements over today’s technology. The assumed efficiency of .380 kWh per mile is taken from the A.D. Little work on full fuel cycle vehicle energy efficiency. Staff is confident that this efficiency level would be achieved in vehicles brought to market in the volume production timeframe.

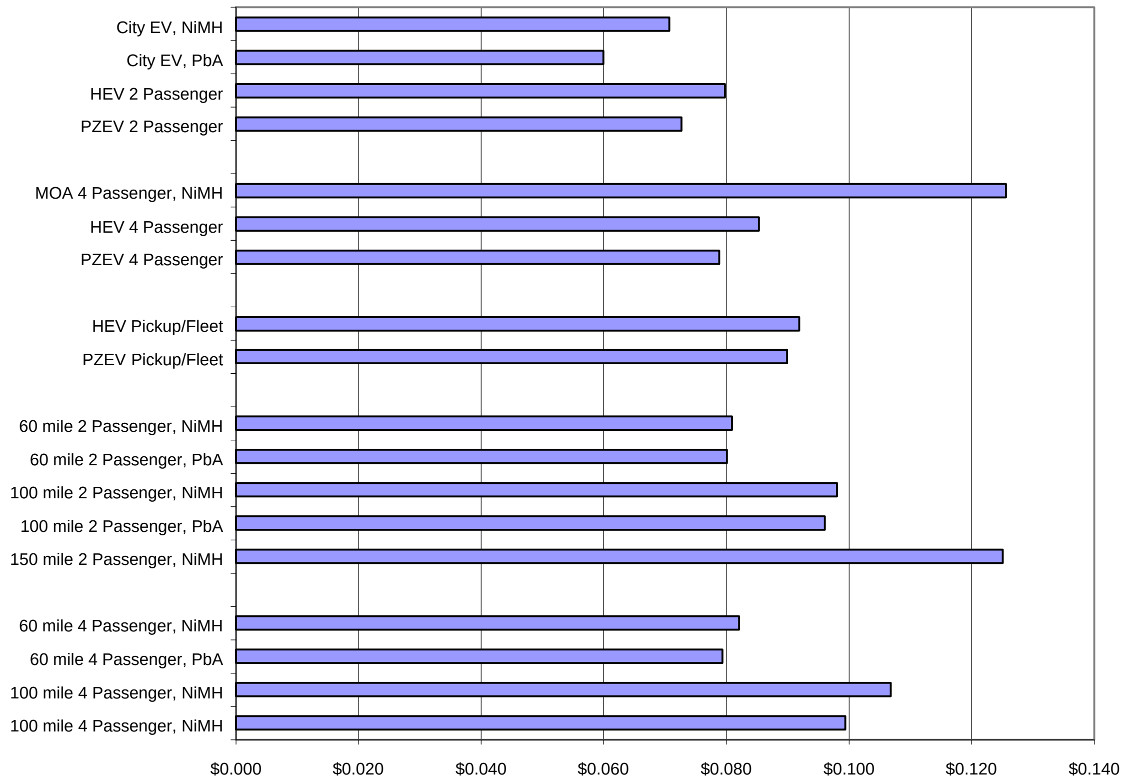
Following the results for the standard vehicles, Table 8-10 shows results for several configurations of high efficiency vehicles. As described in Section 8.3 above, the high efficiency vehicles are assumed to be 2nd or 3rd generation versions of OEM ZEVs with improvements over MOA-era vehicles in several of their efficiency-related attributes. These examples are provided in order to illustrate the effect of efficiency improvement and the resulting reduced battery pack size on vehicle initial cost and lifecycle cost.

Table 8-10
Volume Production Vehicles
Base Case Cost Estimates

Vehicle Type	Battery Type	Charger Cost	Initial Pack Cost	Vehicle Incremental Cost	Total Incremental Cost	Lifecycle Cost per Mile
(Standard Vehicles)						
2 Passenger						
City EV	NiMH	$750	$2,666	$0	$3,416	$0.071
City EV	PbA	$750	$731	$0	$1,481	$0.060
HEV 2 Passenger	NiMH	$0	$586	$500	$1,086	$0.080
PZEV 2 Passenger	NA	$0	$0	$500	$500	$0.073
4 Passenger						
MOA 4 Passenger	NiMH	$750	$9,230	$0	$9,980	$0.126
HEV 4 Passenger	NiMH	$0	$586	$500	$1,086	$0.085
PZEV 4 Passenger	NA	$0	$0	$500	$500	$0.079
Pickup/Fleet						
HEV Pickup/Fleet	NiMH	$0	$586	$500	$1,086	$0.092
PZEV Pickup/Fleet	NA	$0	$0	$500	$500	$0.090
(High Efficiency Vehicles)						
2 Passenger						
60 mile 2 Passenger	NiMH	$750	$2,989	$1,500	$5,239	$0.081
60 mile 2 Passenger	PbA	$750	$1,449	$1,500	$3,699	$0.080
100 mile 2 Passenger	NiMH	$750	$5,098	$1,500	$7,348	$0.098
100 mile 2 Passenger	PbA	$750	$2,553	$1,500	$4,803	$0.096
150 mile 2 Passenger	NiMH	$750	$8,438	$1,500	$10,688	$0.125
4 Passenger						
60 mile 4 Passenger	NiMH	$750	$4,336	$0	$5,086	$0.082
60 mile 4 Passenger	PbA	$750	$2,098	$0	$2,848	$0.079
100 mile 4 Passenger	NiMH	$750	$7,384	$0	$8,134	$0.107
100 mile 4 Passenger	NiMH	$750	$6,593	$0	$7,343	$0.099

Graph 8-2 displays the incremental lifecycle cost for these vehicles.

Graph 8-2
Volume Production Vehicles
Estimated Incremental Lifecycle Cost per Mile



<u>Alternative Scenarios</u>.

Next we present the results of two alternative scenarios. Similar to the alternative scenarios shown for 2003, these scenarios look at higher gasoline prices (using the nominal gasoline price of $1.75 per gallon rather than the pre-tax price of $1.26 per gallon) and higher electricity prices ($0.075 per kWh rather than $0.05 per kWh). Because in future volume production we already assume longer battery life, a separate alternative scenario for battery life is not needed. The results of these scenarios are presented in Tables 8-11 and 8-12.

As is shown in the tables below, the increased price of gasoline increases the lifecycle cost of the HEVs by some 6 to 10 percent, and increases lifecycle cost for the PZEVs by 11 to 17 percent. The increased price of electricity increases lifecycle cost for the battery electric vehicles by about 3 to 6 percent. These results are similar to those reported for the 2003 vehicles.

Table 8-11
Volume Production Vehicles
Alternative Scenario Cost Estimates
(Increased Gasoline Price)

Vehicle Type	Incremental Lifecycle Cost Per Mile Base Case	Increased Gas Price	Difference	Percent
(Standard Vehicles)				
2 Passenger				
City EV, NiMH	$0.071	$0.071	$0.000	0.0%
City EV, PbA	$0.060	$0.060	$0.000	0.0%
HEV 2 Passenger	$0.080	$0.085	$0.005	5.9%
PZEV 2 Passenger	$0.073	$0.081	$0.008	11.4%
4 Passenger				
MOA 4 Passenger, NiMH	$0.126	$0.126	$0.000	0.0%
HEV 4 Passenger	$0.085	$0.092	$0.007	8.0%
PZEV 4 Passenger	$0.079	$0.090	$0.011	13.6%
Pickup/Fleet				
HEV Pickup/Fleet	$0.092	$0.101	$0.009	10.2%
PZEV Pickup/Fleet	$0.090	$0.105	$0.015	16.7%
(High Efficiency Vehicles)				
2 Passenger				
60 mile 2 Passenger, NiMH	$0.081	$0.081	$0.000	0.0%
60 mile 2 Passenger, PbA	$0.080	$0.080	$0.000	0.0%
100 mile 2 Passenger, NiMH	$0.098	$0.098	$0.000	0.0%
100 mile 2 Passenger, PbA	$0.096	$0.096	$0.000	0.0%
150 mile 2 Passenger, NiMH	$0.125	$0.125	$0.000	0.0%
4 Passenger				
60 mile 4 Passenger, NiMH	$0.082	$0.082	$0.000	0.0%
60 mile 4 Passenger, PbA	$0.079	$0.079	$0.000	0.0%
100 mile 4 Passenger, NiMH	$0.107	$0.107	$0.000	0.0%
100 mile 4 Passenger, NiMH	$0.099	$0.099	$0.000	0.0%

Table 8-12
Volume Production Vehicles
Alternative Scenario Cost Estimates
(Increased Electricity Price)

	Incremental Lifecycle Cost Per Mile			
Vehicle Type	**Base Case**	**Increased Elect. Price**	**Difference**	**Percent**
(Standard Vehicles)				
2 Passenger				
City EV, NiMH	$0.071	$0.074	$0.003	4.6%
City EV, PbA	$0.060	$0.063	$0.003	5.2%
HEV 2 Passenger	$0.080	$0.080	$0.000	0.0%
PZEV 2 Passenger	$0.073	$0.073	$0.000	0.0%
4 Passenger				
MOA 4 Passenger, NiMH	$0.126	$0.133	$0.007	5.9%
HEV 4 Passenger	$0.085	$0.085	$0.000	0.0%
PZEV 4 Passenger	$0.079	$0.079	$0.000	0.0%
Pickup/Fleet				
HEV Pickup/Fleet	$0.092	$0.092	$0.000	0.0%
PZEV Pickup/Fleet	$0.090	$0.090	$0.000	0.0%
(High Efficiency Vehicles)				
2 Passenger				
60 mile 2 Passenger, NiMH	$0.081	$0.085	$0.004	5.0%
60 mile 2 Passenger, PbA	$0.080	$0.083	$0.003	3.7%
100 mile 2 Passenger, NiMH	$0.098	$0.102	$0.004	4.0%
100 mile 2 Passenger, PbA	$0.096	$0.100	$0.004	4.1%
150 mile 2 Passenger, NiMH	$0.125	$0.129	$0.004	3.1%
4 Passenger				
60 mile 4 Passenger, NiMH	$0.082	$0.087	$0.005	5.9%
60 mile 4 Passenger, PbA	$0.079	$0.084	$0.005	5.7%
100 mile 4 Passenger, NiMH	$0.107	$0.112	$0.005	4.8%
100 mile 4 Passenger, NiMH	$0.099	$0.104	$0.005	4.6%

8.9 Discussion

This section provides an overview discussion of the cost results for the various scenarios, and also looks at the results for comparable-range lead acid and NiMH vehicles.

8.9.1 2003 Cost Estimates

For 2003, in all cases the incremental initial cost of battery electric vehicles is significantly greater than the incremental initial cost for similar configuration HEVs or PZEVs. The incremental initial cost varies from about $7,500 for City EVs (which have no directly comparable ICE vehicle) to more than $20,000 for freeway capable vehicles with NiMH batteries. By comparison the incremental initial cost is about $3,300 for HEVs and $500 for PZEVs.

On a lifecycle cost per mile basis similar results are obtained—the near-term EVs are significantly more expensive. Looking first at 2 passenger vehicles, the lowest cost is the PZEV at $0.075 per mile. The lowest cost EV is a PbA City EV, which at $0.15 per mile is twice the incremental cost. The freeway capable vehicles have higher costs still.

For 4 passenger vehicles, the NiMH and PbA MOA type vehicles have estimated incremental lifecycle costs of $0.27 and $0.208 per mile respectively. (Please note that these vehicles have different ranges (73 vs. 40 miles) so the costs are not directly comparable. The relative cost of comparable-range NiMH and PbA vehicles is discussed separately below). The cost per mile for the 4 passenger HEVs and PZEVs is estimated at $0.108 and $0.083.

The incremental lifecycle cost per mile for the 2003 EV fleet/pickup vehicles likewise significantly exceeds that of the HEV or PZEV alternatives.

Under alternative scenarios, we assume longer battery life and higher gasoline prices. In that instance, the cost gap narrows. Even with both of these factors taken into account, however, the 2003 battery vehicles are estimated to have a significantly higher lifecycle cost per mile than their conventional counterparts. An increased price of electricity slightly increases the battery vehicle cost premium.

8.9.2 Volume Production Cost Estimates

For future, optimized volume production a different picture emerges. Incremental cost for the EVs is reduced significantly, ranging from about $1300 for a PbA City EV to about $10,000 for a 150 mile freeway capable vehicle. This stems from a reduction in per module battery cost, reduced pack sizes due to more efficient vehicle design, and elimination of the incremental cost associated with the rest of the vehicle.

The estimated incremental lifecycle cost per mile is heavily dependent on the assumed efficiency of the vehicle. The “base case” MOA type four passenger vehicle, which assumes only modest efficiency improvement over today’s vehicles, has an estimated incremental lifecycle cost per mile of $0.126. This is about 60 percent more expensive than the 4 passenger PZEV at $0.079.

If, however, vehicles are built with the efficiency improvements assumed in the other vehicles considered, then several of the battery EVs are roughly comparable to PZEVs on a lifecycle cost basis. For example, in our base case analysis the NiMH and PbA versions of the 2 passenger 60 mile vehicle are $0.081 and $0.080 per mile respectively, while the PZEV is $0.073. The 2 passenger 100 mile vehicles are $0.098 and $0.096 per mile for NiMH and PbA, roughly 35 percent more expensive than the PZEV. The 4 passenger 60 mile EVs are $0.082 per mile for NiMH and $0.079 for PbA and the 4 passenger 100 mile EVs are $0.107 and $0.099 per mile, while the PZEV is $0.079. The City EVs, at $0.071 and $0.060 per mile, are the least expensive of all vehicles considered in the volume production scenario.

Under an alternative scenario, which considers the after-tax gasoline price actually paid by consumers, the lifecycle cost of the 60 mile freeway capable vehicles is equal to or in some cases less than the lifecycle cost of the similar conventional vehicle.

Thus using optimistic but nevertheless plausible assumptions, in volume production the battery EVs could become cost-competitive with conventional vehicles on a lifecycle cost per mile basis.

8.9.3 NiMH Compared to Lead-Acid

In those cases where PbA and NiMH vehicles with the same range are compared, the PbA vehicles have a very minor cost advantage. Table 8-13 below shows the base case cost for three comparable vehicle types, in volume production.

Table 8-13
Incremental Lifecycle Cost per Mile
Same-Range NiMH and PbA Vehicles

Vehicle	Battery Type	Lifecycle Cost per Mile
60 mile 2 passenger	NiMH	.081
	PbA	.080
100 mile 2 passenger	NiMH	.098
	PbA	.096
60 mile 4 passenger	NiMH	.082
	PbA	.079

In the 2003 calculations, the PbA vehicles are less expensive than the similar NiMH vehicles on both an initial cost and a lifecycle cost basis. However, in these instances the PbA vehicles and the NiMH vehicles are not directly comparable because the NiMH vehicles have greater range.

8.9.4 Relative Significance of Various Factors

Staff has performed a limited “sensitivity analysis” to identify how changes in the various assumptions for EVs affect the net present value cost per mile.

Assuming that vehicle performance is held constant, vehicle efficiency has the greatest impact on net present value cost per mile. This is because increased vehicle efficiency allows the use of a smaller battery pack to achieve a given range, and also results in lower fuel costs. For example, in volume production a 50 percent increase in vehicle efficiency, if used to reduce battery pack size by 50 percent, results in about a 50 percent reduction in net present value cost per mile. (The exact magnitude of the change varies according to the starting assumptions used). This example does not consider “second-order” effects, such as the further increase in range made possible by a lighter vehicle weight, which would allow a still smaller battery pack. Such iterative improvements would increase the overall benefit of efficiency gains. In 2003 the impact of a similar efficiency improvement is somewhat diluted, to about 30 percent, due to the large fixed cost associated with vehicle components.

The parameters associated with battery cost also have a significant impact. For example, in volume production a 50 percent increase in battery cost per module results in roughly a 30 percent increase in the net present value cost per mile. Once again the impact is reduced in 2003, to about 16 percent, due to the effect of vehicle incremental cost. Battery life also is important. As was shown in Table 8-7 above, increasing the assumed NiMH battery life from 6 to 10 years results in about a 15 percent reduction in net present value cost per mile. Increasing the assumed life for PbA from 3 to 5 years likewise reduces net present value cost per mile by about 15 percent.

The only other factor with a significant effect is EV incremental cost. Increasing the assumed EV incremental cost by $3,000 results in about an 8 percent increase in net present value cost per mile in 2003, and a 20 percent increase in volume production. Maintenance cost has an intermediate impact. A 50 percent increase in assumed maintenance cost results in roughly a 5 percent increase in net present value cost per mile in 2003 and 12 percent in volume production. The remaining parameters (battery salvage value, electricity cost, inflation rate, discount rate) all have a relatively minor impact.

8.9.5 Conclusions

This section presents incremental cost estimates for a wide variety of vehicle types. For 2003, battery EVs are significantly more expensive than conventional vehicles on both an initial and lifecycle cost basis. This holds true even under alternative scenarios with increased battery life and increased gasoline price.

For volume production, the base case MOA type vehicle is about 60 percent more expensive on a lifecycle cost per mile basis than a comparable PZEV. Highly efficient BEVs, however, can be comparable to conventional vehicles on a lifecycle cost basis.

When volume production NiMH and PbA vehicles with the same range are compared, the PbA vehicles have a very slight cost advantage.

9 ENVIRONMENTAL, ENERGY AND ECONOMIC BENEFITS

9.1 Introduction

ZEVs have the capability to provide comprehensive environmental, energy and societal benefits. As noted above, ZEVs are the "gold standard" with respect to reducing emissions of smog forming pollutants. ZEVs also provide reductions in the emissions of toxic air contaminants from motor vehicles. High-efficiency ZEVs and hybrid electric near-ZEVs also will result in significant reductions in emissions of CO_2 and other greenhouse gases. Vehicles powered by grid electricity will increase the diversity of California's fuel supply and reduce our dependence on imported oil. Electric drive vehicles have the potential to be powered by renewable sources of energy such as wind, hydropower, or solar energy. ZEVs also can benefit California's economy as well as our public health. Because of their high-technology leadership, California companies have the technical and scientific capability to play a significant role in the design, development and production of advanced technology zero emission components and vehicles.

Participants at both public workshops urged that staff fully consider a wide range of environmental benefits from ZEVs. From an air quality standpoint, they recommended additional focus on "real world" emissions, which they contend can be higher than the estimates provided by ARB emission models. They also recommended full consideration of upstream emissions (emissions from refining, transport and refueling) for gasoline vehicles, and a similar emphasis on toxic emissions. They noted that toxic emissions from motor vehicles, fueling infrastructure and refining can have a disproportionate impact on nearby populations, and stated that ARB should recognize the resulting environmental justice implications. Finally, they asked staff to fully consider the CO_2 emissions from internal combustion vehicles and the resulting contribution to global climate change.

Commenters also asked that staff consider multimedia environmental impacts, such as the damage to water quality caused by leaking underground fuel tanks. Commenters also urged ARB to pay attention to the energy diversity implications of different fuel choices. This chapter addresses these issues and quantifies to the extent possible the relative environmental impacts of ZEVs.

9.2 Air Quality Benefits

Due to the ever-increasing growth in vehicle miles traveled, new, extremely clean vehicle technologies are necessary if California is to meet health-based air quality standards. This section documents the need for further improvements, then discusses the air quality impacts that result from the use of electric and other vehicle technologies in the South Coast Air Basin. Information is presented for smog precursors, toxic air contaminants, and carbon dioxide.

This complete analysis of vehicle emissions covers both direct and indirect emissions on a per vehicle basis and for the vehicle fleet as a whole. The information is drawn from two main data sources. The ARB EMFAC2000 motor vehicle emission inventory provides the basis for estimates of direct emissions at both the individual vehicle and the fleet level. Please note that the evaporative emission results reflect revisions to the evaporative model to reflect new data and analysis not included in the published version. Staff will be seeking Board approval for these minor revisions.

Our estimates of per vehicle indirect emissions are based on contract work performed by A.D. Little (formerly Acurex Environmental). The fleet-wide indirect emission estimate uses both sources--per vehicle indirect estimates from A.D. Little are multiplied by fleet activity estimates taken from the emission inventory.

9.2.1 The Need for Air Quality Improvements

Although significant strides have been made toward improving California's air quality, health-based state and federal air quality standards continue to be exceeded in regions throughout California. Areas exceeding the federal 1-hour ozone standard include the South Coast Air Basin, San Diego County, the San Joaquin Valley, the Southeast Desert, the Broader Sacramento area and Ventura County. With promulgation of the new federal eight-hour ozone standard, more areas of the State are likely to be designated as nonattainment.

Ozone, created by the photochemical reaction of reactive organic gases and oxides of nitrogen, leads to harmful respiratory effects including lung damage, chest pain, coughing, and shortness of breath, especially affecting children and persons with compromised respiratory systems. Other environmental effects from ozone include agricultural crop damage. In addition, because ozone precursors, such as NOx, also react in the atmosphere to form particulate matter (PM), reductions in NOx will be crucial to meet existing state and federal PM_{10} standards, as well as the new federal standards for fine particulate matter ($PM_{2.5}$). Thus, even though direct emissions of particulate matter are negligible for both EVs and gasoline vehicles, reductions in NOx brought about by EVs will help address the particulate matter problem. Toxic air contaminants are substances that may cause or contribute to an increase in cancer or serious illness, such as respiratory disease. The sources of toxic emissions include many products, services, industrial processes, and motor vehicles. The high potential of the ZEV program to reduce toxic emissions, and a focus on ARB's mission to promote and protect public health, are an impetus for ARB staff to begin quantifying the releases of toxic air contaminants from various vehicle technologies.

California's plan for achieving the federal 1-hour ozone standard is contained in the California State Implementation Plan (SIP) that was approved by the Board in 1994. A significant part of the SIP pertains to the control of mobile sources, which are estimated to account for approximately 60 percent of ozone precursors statewide. The SIP calls for new measures to cut ozone precursor emissions from mobile sources to half of what the emissions would be under existing regulations. Specific control measures to reduce emissions from most types of motor vehicles, including light duty vehicles, are included in the SIP. The SIP calls for additional motor vehicle emission reductions in the South Coast Air Basin of approximately 75 tons per day reactive organic gases (ROG) plus NOx (these emission reductions are referred to as the mobile source “Black Box”). Specific approaches to fully achieve these additional emission reductions have not yet been identified.

One purpose of the ZEV program is to address the requirements of California’s SIP by introducing advanced technology measures to achieve additional emission reductions needed for the South Coast Air Basin. The reductions will help ensure continued statewide progress toward meeting state and federal air quality standards for ozone and particulate matter. The ZEV program will help achieve and maintain the federal one-hour ozone standard in regions such as the San Joaquin Valley and the Sacramento area, the federal eight-hour ozone and particulate matter standards in a number of areas, and the State ozone and particulate matter standards throughout California.

9.2.2 Per Vehicle Emissions

This section compares the direct and indirect emissions, at the per vehicle level, that result from several different vehicle technologies. Information is presented here for NMOG, NOx, and toxic air contaminants. (CO_2 emissions are discussed in Section 9.4 below.) ARB recognizes the importance of including toxic air contaminants when evaluating motor vehicle emission impacts. Various interested parties emphasized this need during both public workshops.

Historically, when assessing the impact of motor vehicles and developing regulations, the ARB only evaluated direct vehicle emissions. The introduction of the ZEV requirement in 1990 brought a fundamental change in the way vehicle technologies are compared due to the shift in emissions away from the vehicle. Any comparison of ZEV technology with conventional vehicles must include both direct and indirect emissions (e.g. power plant emissions associated with a battery electric vehicle, and refinery and refueling emissions from gasoline vehicles) to accurately assess a vehicle’s overall environmental impact.

While ARB staff recognizes that the vehicles analyzed would be used throughout California, all comparisons are restricted to the South Coast Air Basin. Due to the information available, this provides the fairest possible comparison.

Vehicle Technologies Evaluated

In comparing per-vehicle direct and indirect emissions, ARB staff has included several vehicle technologies that could be available to meet the ZEV requirements in 2003. These technologies represent a plausible mix of vehicles for 2003 (auto manufacturers have indicated that they plan to produce a combination of gasoline-fueled vehicles and battery electric vehicles to meet the early ZEV requirements). The vehicle types evaluated include:

- Battery electric vehicle
- Gasoline vehicle eligible for 0.2 partial ZEV allowance (PZEV SULEV)
- Gasoline non-grid connected HEV eligible for 0.3 partial ZEV allowance (PZEV HEV non-grid)
- Non-PZEV SULEV vehicle (SULEV)
- Non-PZEV SULEV vehicle with higher in-use deterioration (SULEV with high LEV II deterioration rates)
- Average model year 2002 vehicle (MY 2002 vehicle)

Direct Emissions

Direct emissions include tailpipe and evaporative emissions from the vehicle itself. EMFAC2000 was used to provide the average lifetime direct emissions of NMOG and NOx. As noted above, the evaporative results presented here reflect revisions to the published version. Table 9-1 provides the direct emissions that result from each vehicle technology, presented on a gram per mile basis. As is shown in Table 9-1, BEVs are truly the “gold standard” for direct emissions.

Table 9-1
Estimated Direct Emissions Per Vehicle
(Tailpipe and Evaporative)

Vehicle Type	Tailpipe (g/mi)			Evaporative (g/mi)	
	NMOG	NOx	Toxics	NMOG	Toxics
BEV	0	0	0	0	0
PZEV SULEV	0.0067	0.024	0.0025	0.020	0.0007
PZEV HEV non-grid	0.0067	0.024	0.0025	0.020	0.0007
SULEV	0.0073	0.025	0.0027	0.032	0.0011
SULEV with LEV II DR	0.0150	0.030	0.0056	0.032	0.0011
MY 2002 vehicle	0.0620	0.173	0.0230	0.049	0.0016

Indirect Emissions

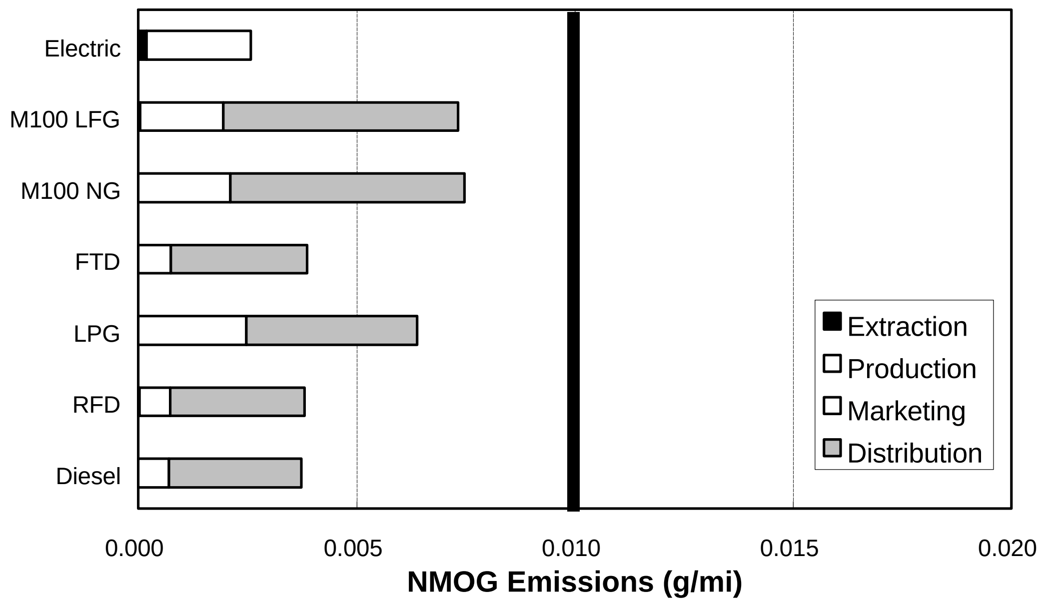
As direct emissions from motor vehicles are reduced, the indirect emissions that result from vehicle refueling, fuel transportation, fuel processing, and feedstock extraction represent a larger share of the total emissions that are attributed to vehicle operation. To quantify these indirect emissions, ARB contracted with

Acurex Environmental in 1993 (now part of A. D. Little) to examine the full fuel cycle emissions for a variety of fuels. The final report, entitled "Evaluation of Fuel-Cycle Emissions on a Reactivity Basis," was completed in September 1996. The fuels evaluated included conventional gasoline, Phase 2 reformulated gasoline, diesel, liquefied petroleum gas (LPG), methanol from natural gas, M85 from biomass, ethanol, compressed natural gas, liquefied natural gas, hydrogen, and electricity.

In November 1998, the ARB adopted the LEV II regulations that, in part, allow vehicles that use fuels with extremely low fuel-cycle emissions to receive an additional ZEV allowance of up to 0.2. As noted above, the fuel-cycle emissions upon which this ZEV allowance is based include all emissions associated with the production, marketing, and distribution of a fuel. To receive this additional partial ZEV credit, the marginal NMOG emissions associated with a fuel used by a vehicle must be lower than or equal to 0.010 grams per mile. The results of the Acurex report were used to determine whether a vehicle using a certain fuel is eligible to receive additional credit toward the ZEV requirement.

To refine the results for several fuels that were found to have NMOG emissions not significantly above or below the 0.010 grams per mile cutpoint, the ARB again contracted with the same consultants, now part of A.D. Little, in 1999. The objective of this study was to refine the emissions estimates on a per-vehicle-mile basis for diesel fuel and LPG for internal combustion vehicles, and methanol for fuel cell powered vehicles. As shown in Figure 9-1, the marginal NMOG emissions for each of the fuels evaluated is lower than 0.010 grams per mile. Consequently, vehicles using these fuels and meeting the applicable partial ZEV requirements would received the additional ZEV allowance of 0.2.

Figure 9-1
Marginal NMOG Emissions in the South Coast



M100 LFG: Methanol from landfill gas
M100 NG: Methanol from natural gas
FTD: Fischer-Tropsch diesel
LPG: Liquefied petroleum gas
RFD: Reformulated diesel

Table 9-2 provides estimates of the indirect emissions for the vehicle technologies examined above. The emission estimates in Table 9-2 represent the marginal emissions expected in the South Coast Air Basin (SCAB) in 2010. Of the three scenarios presented in the 1996 A.D. Little report that evaluated the marginal emissions in the SCAB in 2010, ARB staff chose to include the middle estimates in Table 9-2. The report did not assess vehicle exhaust emissions (other than CO_2 which is proportional to fuel consumption) or vehicle evaporative emissions.

Table 9-2
Estimated Indirect Emissions Per Vehicle
South Coast Air Basin in 2010

Vehicle Type	Fuel Cycle (g/mi)		
	NMOG	NOx	Toxics1
BEV	0.0020	0.003	0.0010
PZEV SULEV	0.0310	0.016	0.0060
PZEV HEV non-grid	0.0210	0.011	0.0040
SULEV	0.0310	0.016	0.0060
SULEV with LEV II DR	0.0310	0.016	0.0060
MY 2002 vehicle	0.0310	0.016	0.0060

1. Toxic weighting: Formaldehyde 1.0; Acetaldehyde 0.5; Benzene 4.8; 1,3 Butadiene 28.0

As Table 9-2 shows, per vehicle indirect emissions from BEVs are significantly lower than the indirect emissions from all other vehicle technologies evaluated. NMOG emissions are reduced by at least a factor of 10, NOx emissions are reduced by more than two-thirds, and toxic emissions are reduced by nearly three-quarters.

Total Emissions

Table 9-3 below presents the estimated total (direct plus indirect) per-vehicle emissions that result from the operation of the various vehicle types.

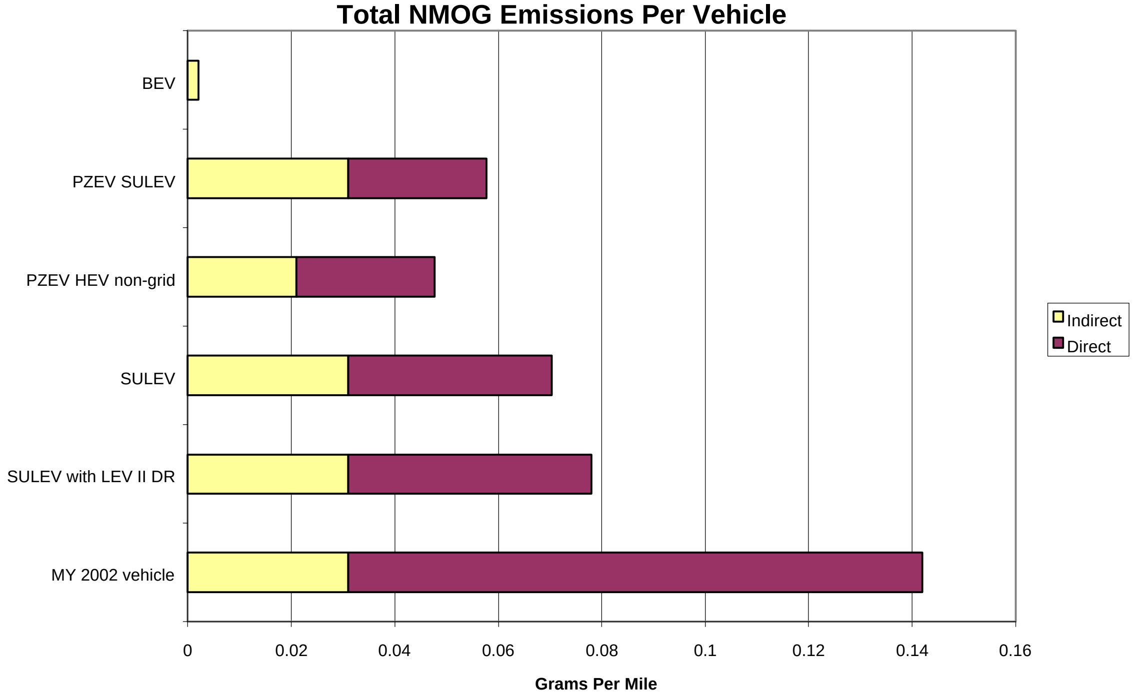
Table 9-3
Total Emissions Per Vehicle
(Grams per mile)

Vehicle Type	NMOG	NOx	Toxics
BEV	0.0020	0.003	0.0010
PZEV SULEV	0.0577	0.040	0.0092
PZEV HEV non-grid	0.0477	0.035	0.0072
SULEV	0.0703	0.041	0.0098
SULEV with LEV II DR	0.0780	0.046	0.0127
MY 2002 vehicle	0.1420	0.189	0.0306

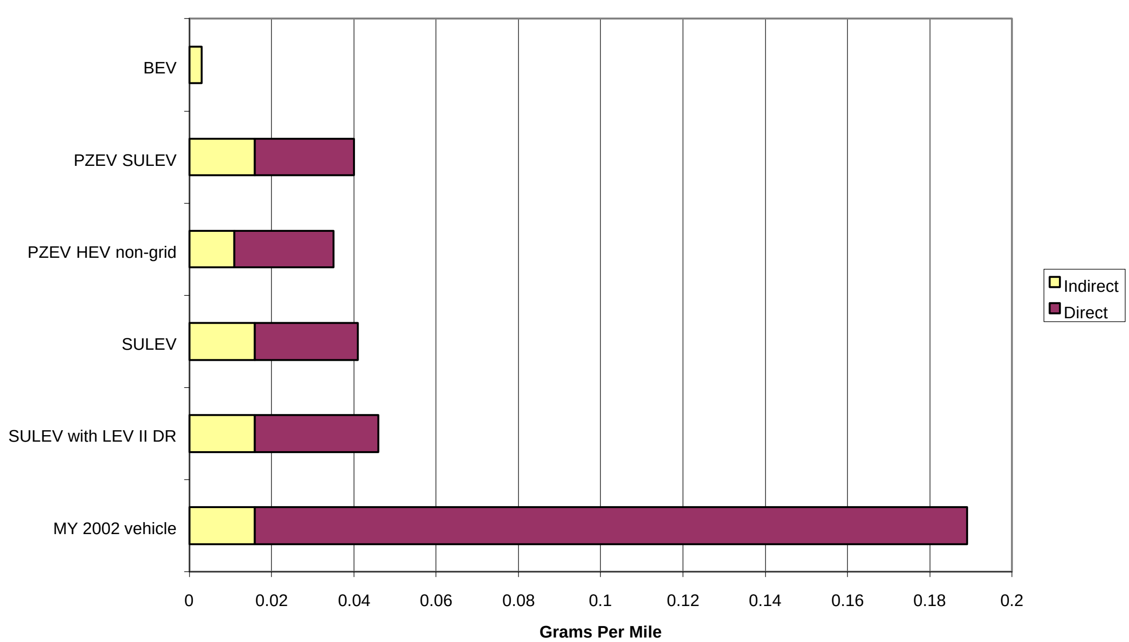
As Table 9-3 illustrates, taking into account both direct and indirect emissions, the per-vehicle emission reductions associated with BEVs are even more dramatic and occur across all pollutants. NMOG emissions are about 96 percent lower than those from the cleanest gasoline vehicle, NOx emissions are about 91 percent lower, and toxic emissions are reduced by more than 86 percent.

Graphs 9-1 through 9-3 show this information in graphic form.

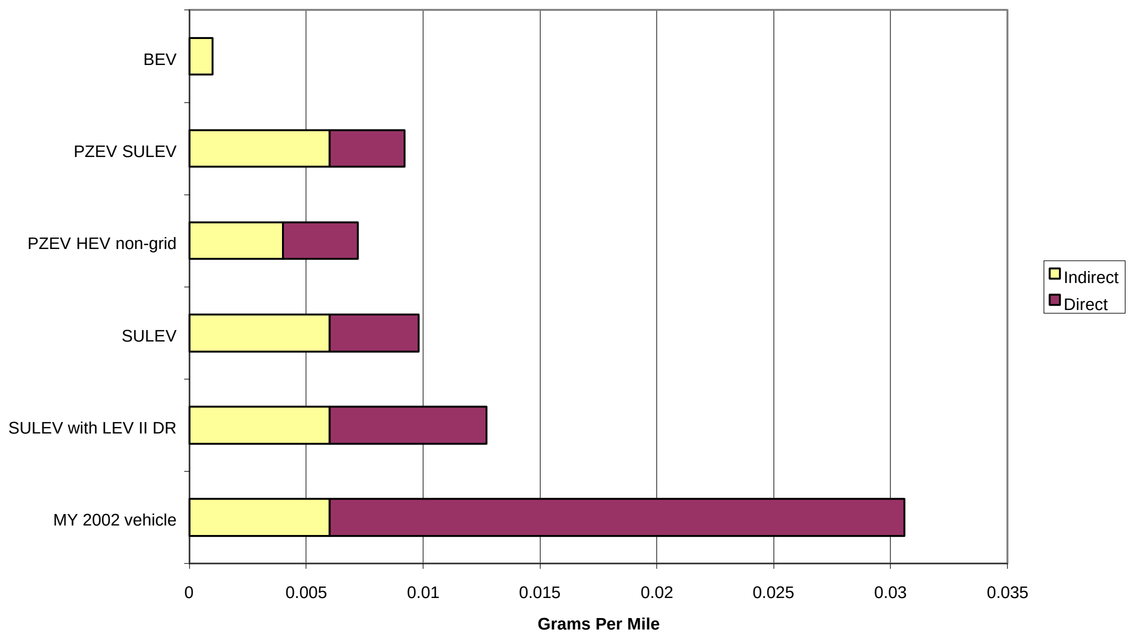
Graph 9-1
Total NMOG Emissions Per Vehicle



Graph 9-2
Total NOx Emissions Per Vehicle



Graph 9-3
Total Air Toxics Emissions Per Vehicle



9.2.3 Fleet-Wide Emissions

To assess and update the fleet-wide emissions benefit of the current ZEV program, ARB staff conducted an emissions impact analysis using the updated on-road emissions inventory model, EMFAC2000. The ARB approved this version of the model on May 25, 2000. As noted above, the evaporative results presented here reflect changes from the published version. The results of the analysis represent various implementation scenarios in the South Coast Air Basin and include the emissions from passenger cars and light-duty trucks weighing less than 3,501 pounds gross vehicle weight.

<u>2010 Scenarios</u>

The analysis compares the emissions from three potential scenarios to a baseline scenario. These scenarios quantify the 2010 emissions in the South Coast Air Basin from light-duty vehicles sold in the years 2003 through 2010. Older vehicles are excluded from this calculation.

- The baseline scenario examines the emissions that would result if no pure ZEVs are sold. Instead, the overall fleet average standard is met with a mix of conventional vehicles.

- Scenario 1 assumes that 10 percent of all vehicles sold during the 2003 to 2010 timeframe are pure ZEVs. Thus in this scenario there are no "multipliers" for vehicle range.

- Scenario 2 represents the introduction of fewer ZEVs (less than 10 percent). This scenario assumes that the average ZEV has an all-electric range of 125 miles. Current regulations provide additional credit for vehicles that have more than 100 miles of all-electric range through model year 2007. The 125 mile range assumption decreases the number of vehicles placed to 3.3 percent from 2003 through 2005, 6.7 percent in 2006 and 2007, and 10 percent in 2008 through 2010.

- Scenario 3 assumes that automakers meet the 4 percent pure ZEV requirement with electric vehicles having an average range of 125 miles (thus reducing the numbers of vehicles required) and the remaining 6 percent requirement with PZEV technologies.

Direct Emissions. Table 9-4 provides estimates of direct fleet-wide tailpipe and evaporative vehicle emissions for the scenarios described above.

Table 9-4
Direct Vehicle Emissions
South Coast Air Basin in 2010
(Tons per day)*

Scenario	ROG Exhaust	ROG Evap	NOx	Total ROG+NOx
Baseline--No ZEVs	4.45	3.67	12.82	20.94
1. 10% ZEVs, no multipliers	4.33	3.30	11.82	19.45
2. 10% ZEVs, with multipliers	4.35	3.47	12.20	20.02
3. 4% ZEVs, 6% PZEVs, with multipliers	4.28	3.42	11.53	19.23

*Estimates include only those vehicles sold in model-years 2003 to 2010; other vehicles excluded

Table 9-5 below presents the reduction in emissions for each scenario as compared to the baseline. As shown in Table 9-5, the reduction in total emissions for each scenario ranges from 0.92 to 1.71 tons per day. Staff notes that scenario 3 (4 percent ZEVs, 6 percent PZEVs, with multiple credits) actually results in greater emission reductions than scenario 2 (10 percent ZEVs, with multiple credits). This does not mean that PZEVs are cleaner than ZEVs. As was shown above, ZEVs are dramatically cleaner on a per-vehicle basis. Rather, these scenario results show the effect of large numbers of PZEVs replacing "fleet average" vehicles. Because PZEVs only generate 0.2 ZEV credit, at least 5 PZEVs are needed to offset 1 ZEV. In addition, because a 125 mile ZEV generates 2.67 credits per vehicle in 2003, each 2003 ZEV is the equivalent of 13 PZEVs (5 x 2.67). Thus reducing the number of ZEVs results in the need for large numbers of PZEVs, which replace vehicles that otherwise would have higher emission levels.

The consistency of the fleet totals across the various scenarios reflects the truly remarkable conventional vehicle emission reductions that have been achieved to date and are projected for the future, in particular as a result of the LEV II regulations.

Table 9-5
Reduction in Direct Vehicle Emissions As Compared to Baseline
South Coast Air Basin in 2010
(Tons per day)*

Scenario	ROG Exhaust	ROG Evap	NOx	Emission Reductions
1. 10% ZEVs, no multipliers	0.12	0.37	1.00	1.49
2. 10% ZEVs, with multipliers	0.10	0.20	0.62	0.92
3. 4% ZEVs, 6% PZEVs, with multipliers	0.17	0.25	1.29	1.71

* Estimates include only those vehicles sold in model-years 2003 to 2010; other vehicles excluded

The estimates in Table 9-5 provide a comparison of direct vehicle emissions and their overall fleet impact. As was noted above, the emission reductions for scenario 3 are similar to scenario 1 and greater than scenario 2 due the high number of PZEVs (30 percent of total production) required to meet the 6 percent ZEV requirement.

<u>Indirect and Total Emissions</u>. To provide a comprehensive evaluation of the benefits of the ZEV program, these emissions must be added to the indirect emissions quantified by A.D. Little. Table 9-6 presents total (direct plus indirect) emissions for the three scenarios compared to the baseline. As shown in Table 9-6, due to upstream emissions, the total emissions from the baseline scenario are 27.45 tons per day in the South Coast Air Basin.

Table 9-6
Total Fleet Emissions
South Coast Air Basin in 2010
(Tons per day)*

Scenario	ROG Exhaust	ROG Evap	ROG Upstream	NOx	NOx Upstream	Total ROG+NOx
Baseline--No ZEVs	4.45	3.67	4.29	12.82	2.22	27.45
1. 10% ZEVs, no multipliers	4.33	3.30	3.89	11.82	2.04	25.38
2. 10% ZEVs, with multipliers	4.35	3.47	4.01	12.20	2.09	26.12
3. 4% ZEVs, 6% PZEVs, with multipliers	4.28	3.42	4.18	11.53	2.16	25.57

* Estimates include only those vehicles sold in model-years 2003 to 2010; other vehicles excluded

Table 9-7 below presents the emission reduction for each scenario as compared to the baseline. As is shown in the table, scenarios 1, 2 and 3 result in emission reductions of 2.07, 1.33 and 1.88 tons per day respectively as compared to the baseline.

Table 9-7
Reduction in Total Vehicle Emissions As Compared to Baseline
South Coast Air Basin in 2010
(Tons per day)*

Scenario	ROG Exhaust	ROG Evap	ROG Upstream	NOx	NOx Upstream	Total ROG+NOx
1. 10% ZEVs, no multipliers	0.12	0.37	0.40	1.00	0.18	2.07
2. 10% ZEVs, with multipliers	0.10	0.20	0.28	0.62	0.13	1.33
3. 4% ZEVs, 6% PZEVs, with multipliers	0.17	0.25	0.11	1.29	0.06	1.88

* Estimates include only those vehicles sold in model-years 2003 to 2010; other vehicles excluded

In public comments, automakers have stated that the air quality benefits of the ZEV program are relatively minor. Staff recognizes that in the near term, due to the small amount of ZEV penetration and the significant improvement in conventional vehicle emissions resulting from LEV II, fleet-wide benefits are modest. To place these emissions reductions in context, however, it is important to note that on a per-vehicle basis ZEVs are significantly cleaner than even the cleanest conventional alternative. Thus, they offer great potential for significant emission reductions over time, as large numbers of ZEVs enter the fleet. The next section explores this issue in more detail.

Long-Term Scenario (2020)

As discussed above, new vehicle technologies are necessary if California is to meet health-based air quality standards. When the ZEV program was adopted in

1990, the intent of the Board was to provide the regulatory push needed for environmentally beneficial technologies to compete in a mature and extremely competitive industry. Even then, the Board and staff acknowledged that for the program to have a significant contribution in helping California meet state and federal air quality standards, much larger percentages of vehicles introduced must be ZEVs. In keeping with this vision, staff modeled the emission benefits that would result in 2020 if 50 percent of all passenger and light-duty vehicles on the road in 2020 were ZEVs. Scenario 4 assumes a ZEV ramp-up beginning in 2003 and further assumes that automakers produce 25% SULEVs during the 2010 to 2020 timeframe, regardless of the NMOG fleet average standard.

Note that these estimates are for direct vehicle emissions only, and do not include upstream emissions. Staff does not have information to support an upstream emission analysis at this time. As was shown for 2010 fleet emissions, however, upstream emissions have a sizable impact on the total. Therefore the results shown here are conservative and do not fully account for all ZEV benefits.

Table 9-8 presents the results of this scenario, along with estimates of the 2020 emissions for the three scenarios discussed above. These results illustrate the importance of pursuing a future in which California fundamentally changes the technology used for personal transportation.

Table 9-8
Direct Fleet Emissions in 2020*
South Coast Air Basin
(Tons per day)*

Scenario	ROG Exhaust	ROG Evap	NOx	Total ROG+NOx
Baseline--No ZEVs	6.73	14.86	17.02	38.61
1. 10% ZEVs, no multipliers	6.44	13.38	15.34	35.16
2. 10% ZEVs, with multipliers	6.43	13.72	15.54	35.69
3. 4% ZEVs, 6% PZEVs, with multipliers	6.41	13.55	15.18	35.14
4. 50% ZEV fleet penetration	4.37	11.80	10.69	26.86

* Estimates include only those vehicles sold in model-years 2003 to 2020; other vehicles excluded

Table 9-9 below presents the difference in emission benefits for each scenario as compared to the baseline.

Table 9-9
Reduction in Direct Vehicle Emissions As Compared to Baseline
South Coast Air Basin in 2020
(Tons per day)*

Scenario	ROG Exhaust	ROG Evap	NOx	Total ROG+NOx
1. 10% ZEVs, no multipliers	0.29	1.48	1.68	3.45
2. 10% ZEVs, with multipliers	0.30	1.14	1.48	2.92
3. 4% ZEVs, 6% PZEVs, with multipliers	0.32	1.31	1.84	3.47
4. 50% ZEV fleet penetration	2.36	3.06	6.33	11.75

* Estimates include only those vehicles sold in model-years 2003 to 2020; other vehicles excluded

As is shown in Table 9-9, the total NMOG plus NOx benefit of Scenario 4 when compared to the “no ZEV” baseline scenario is 11.75 tons per day in the South Coast. This is a reduction of more than 30 percent from the baseline level, illustrating the gains that are possible with significant levels of ZEV introduction.

9.2.4 Community Level Impacts

At the public workshops, commenters also urged that staff consider the environmental justice implications of toxic emissions from motor vehicles and refineries. Staff recognizes that mobile source pollution from highway traffic may disproportionately affect nearby inner city and low-income neighborhoods. For example, the Multiple Air Toxics Exposure Study conducted in the South Coast Air Basin found that mobile sources were the greatest contributor to carcinogenic risk in the basin. At sites with the greatest risk levels, the dominance of mobile sources was even greater than at the other sites. Refineries and other production and distribution facilities may have similar effects on nearby communities. Reductions in toxic emissions from motor vehicles and related fueling infrastructure can thus help address community level public health concerns.

The Board has recently announced the formation of a new Community Health Program to address how exposure to numerous air toxic sources affects specific neighborhoods. For the first time, the ARB will address strategies to reduce the cumulative effects of exposure from multiple sources of air toxics.

9.3 Releases to Other Environmental Media

Above and beyond their air pollution benefits, ZEVs can make significant positive contributions in other environmental areas. Just as the gasoline refining, marketing and distribution system results in air pollution emissions, it likewise results in water pollution due to fuel leakage and wastewater discharges, and is a source of hazardous waste.

The fuel distribution system in California is tightly regulated. Nevertheless, given the enormous quantities of fuel involved (roughly 40 million gallons of gasoline sold per day in California) it is inevitable that leakage occurs. The impact of such leaks can be significant.

One example is the contamination of groundwater by leaking underground storage tanks. Certainly the most well known recent case involves the contamination of drinking water supplies by MTBE. It is important to bear in mind, however, that in addition to MTBE gasoline contains numerous other toxic compounds, including benzene, toluene, and 1,3 butadiene. Therefore the removal of MTBE from gasoline will not eliminate the danger of water pollution from fuel leakage.

In addition to the threat posed by leaking storage tanks, the fuel distribution system also introduces water pollution in the form of point source discharges from refineries. According to figures reported by industry as part of the annual Toxic Release Inventory (TRI) program, there are 22 facilities in California that fall under Standard Industrial Classification Code 2911, petroleum refining. For the 1998 reporting year, 10 of these 22 facilities reported discharges to surface water, totaling more than 7.3 million pounds. Chemicals released included nitrate compounds, MTBE, and methanol. In that same reporting year, 13 of the 22 facilities reported releases to publicly owned treatment works (wastewater treatment facilities). Chemicals released included phenol, MTBE and methanol, and total releases were almost 1.5 million pounds.

The fuel production and distribution system also results in the generation of hazardous waste. According to manifest data from the Department of Toxic Substances Control, the 22 refineries noted above generated more than 103,000 tons of hazardous waste in 1998.

Because the use of battery electric vehicles and hybrid electric vehicles reduces gasoline demand, widespread adoption of these technologies would have a positive impact on water quality and hazardous waste generation.

Although not directly related to the fuel distribution system, motor oil from internal combustion engine vehicles is also a significant source of water pollution. Motor oil contains polycyclic aromatic hydrocarbons (PAHs), which are a major water toxicity problem in urban areas. Motor oil is released to the environment during the normal operation of internal combustion engine vehicles, and also when used motor oil is improperly disposed. Electric vehicles do not need motor oil and therefore do not contribute to this problem.

9.4 Energy Diversity and Energy Demand Benefits

Reducing demand for gasoline can have important benefits for California. First, a reduction in demand could help eliminate shortages of cleaner-burning California gasoline that have lead to rapid price increases. Second, a successful effort to reduce gasoline demand also would reduce the need for additional refining, transportation and distribution facilities, thus reducing air and water pollution as noted above.

The Task Force on California Gasoline Prices, convened by the Attorney General, recently examined gasoline supply and demand issues as they relate to gasoline price increases. The Attorney General, in his comments on the Task Force work, noted that high gasoline prices erode the competitiveness of California's industries and reduce the real income of our citizens.

Gasoline demand can be reduced by increasing the efficiency with which gasoline is used, and by the use of alternative fuels. Advanced vehicle design, lightweight components, aerodynamic advances and the use of electric drivetrains all result in increased vehicle efficiency. EVs and hybrid electric vehicles typically take advantage of such measures and, as a result, achieve higher efficiencies. Battery EVs, which use electricity as a fuel, provide significant alternative fuel benefits because electricity can be produced from a variety of non-petroleum energy resources. Moreover, because both electricity and hydrogen can be produced from renewable resources such as solar, wind or hydropower, or biomass feedstocks, these technologies can help pave the way towards a sustainable energy future.

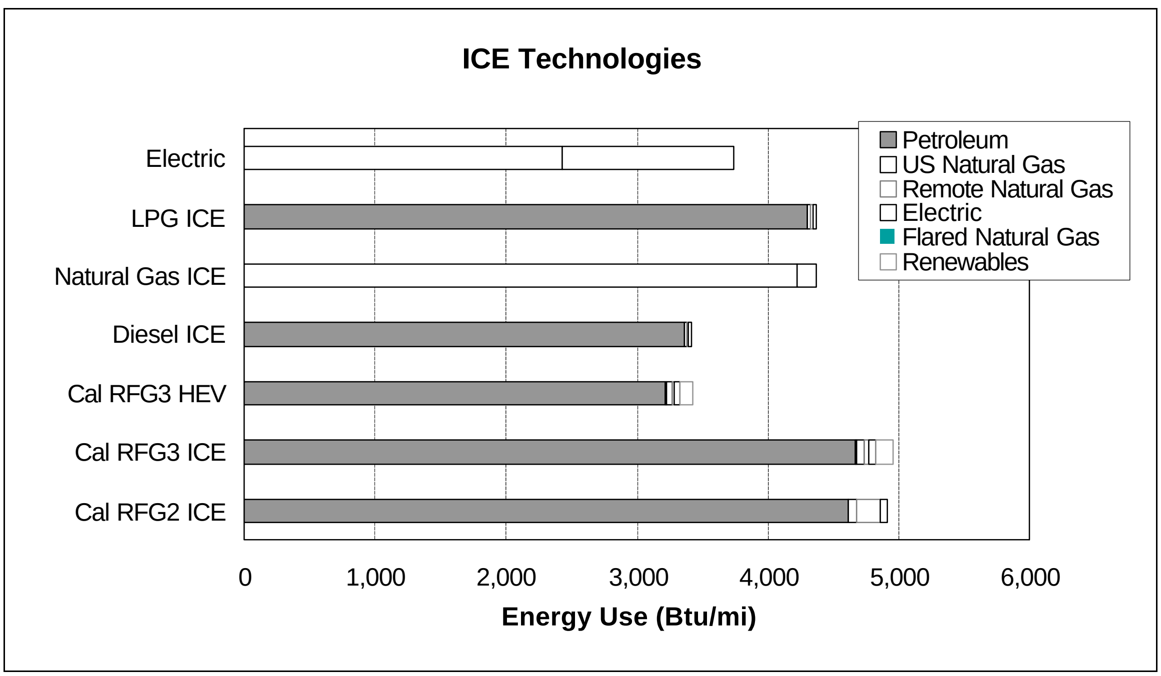
The Task Force formed a Conservation Work Group that looked specifically at conservation and efficiency measures that can reduce demand for gasoline. The Conservation Work Group agreed that the Task Force should recommend policies to encourage vehicle efficiency, fuel substitution, and alternative modes of transportation. The Conservation Work Group further agreed that the state should examine its environmental and energy programs and give preference to programs that simultaneously address environmental problems and reduce gasoline consumption. Task Force members generally agreed that conservation measures are worthy of further analysis and debate.

The Attorney General recommended that the State take aggressive steps to increase fuel economy and the use of alternative fuels, and supports taking steps to ensure the state optimizes conservation and alternative fuel opportunities. Such actions, by reducing the pressure on supplies of clean-burning California gasoline, would help mitigate shortages and the resulting price spikes. ARB staff concurs that EVs and high efficiency hybrid vehicles provide important energy supply and diversity advantages.

To quantify the relative efficiencies of current and future technologies, the ARB and the Energy Commission contracted with A.D. Little to perform an analysis of the full fuel cycle energy efficiency of various vehicle technologies. A technical advisory committee with members from each of the affected fuels was established to provide additional expertise and guidance. This work would also serve to quantify the relative global greenhouse gas benefits of each technology by quantifying total carbon dioxide emissions. Energy conversion efficiency of a fuel was determined for the fuel production and energy conversion portions of the fuel cycle, including fuel acquisition and refining, distribution, refueling, and in-vehicle consumption

The A.D. Little study determined that, at the vehicle level, battery electric vehicles had the highest "miles per equivalent gallon" energy efficiency of all vehicle types analyzed, followed by hydrogen fuel cell and methanol fuel cell vehicles and hybrid electric vehicles. However, on a total fuel-cycle energy use basis, diesel internal combustion engine vehicles and gasoline hybrid electric vehicles used the least energy per mile, followed by electric vehicles. When compared to conventional vehicles, electric vehicles consume approximately 25 percent less energy on a full fuel cycle basis. It should be noted that there was significant debate between technical advisory committee members on the estimated electric vehicle efficiency in 2010. ARB staff believes these results conservatively represent the overall energy use of electric vehicles. These results are presented in Figure 9-4.

Figure 9-4
Energy Consumption Results



LPG: Liquefied Petroleum Gas
Cal RFG2: Phase 2 reformulated gasoline
Cal RFG3: Phase 3 reformulated gasoline

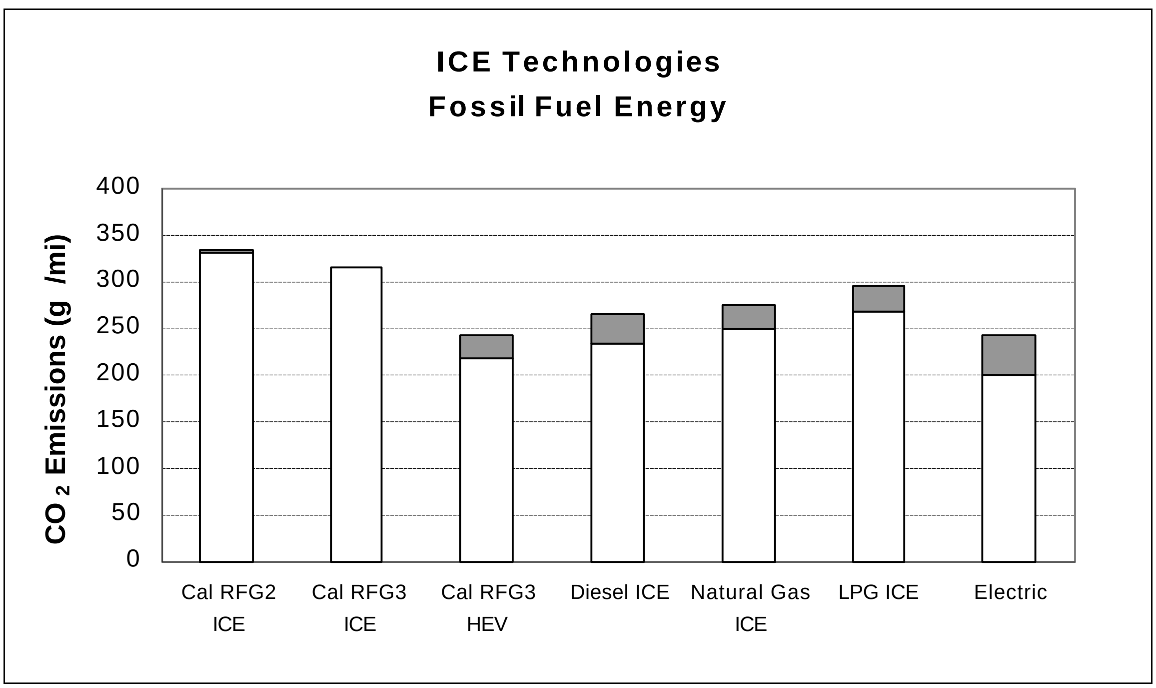
Emissions of greenhouse gases from vehicle exhaust and the energy conversion efficiency of the vehicle were calculated directly from vehicle fuel economy, carbon weight percentage of the fuel, fuel energy, and fuel density.

There are several other general conclusions that can be drawn from the report:

- Vehicle energy consumption has the largest effect on total fuel cycle and vehicle energy and CO_2 emissions.
- Energy demand and CO_2 emissions for EVs are strongly driven by the new California generation mix.
- Marginal energy assumptions are consistent with electric power generation mix from new natural gas combined cycle power plants.
- Fuel cell technologies, electric vehicles, and gasoline HEVs result in similar CO_2 emissions.

As shown in Figure 9-5, electric vehicles have the lowest carbon dioxide emissions of the technologies evaluated.

Figure 9-5
CO_2 Emissions Comparison



9.5 Secondary Economic Benefits

ARB currently has contract work underway to identify and assess the secondary economic benefits of the ZEV regulations, especially to California. Such secondary benefits include:

- the economic activity generated by automaker efforts to meet the ZEV requirement with pure EVs,
- improvements in technology spurred by the ZEV requirement but applied to products other than pure EVs, and
- the benefits of those applications to the economy and to consumers of products other than EVs.

Staff expects that information from this study will be available for consideration by the Board at the September Board meeting.

10 CONCLUSION

10.1 A Blueprint for Further Progress

In order to successfully place the vehicles required under the ZEV program regulations, and achieve the resulting long-term air quality and other environmental benefits, several things need to be in place.

First, the technology must have arrived at the point where reliable vehicles are available, with performance characteristics sufficient to meet a range of market applications. Based on the investigation discussed in this report, staff concludes that today's EVs clearly meet this test. Although real world vehicle range is limited and long recharge times are necessary, a variety of attractive platforms are available and vehicles are in everyday use in many different circumstances across the state. All evidence and testimony points to the fact that those who are using today's EVs are very pleased with their performance. With regard to PZEVs, manufacturers have testified that it will be difficult for some automakers to take full advantage of the PZEV option in 2003, due to the lead time necessary to convert a significant portion of the fleet to PZEV status.

Second, market applications must exist that can absorb the necessary number of vehicles. Although this portion of the analysis is necessarily more speculative than the technology review, as reported in the EV Market section staff has identified a number of applications that are well suited to the use of ZEVs. Staff recognizes that actual placement of vehicles in these possible applications will be challenging given the competing choices available.

Third, the vehicles must be available at prices that are competitive to conventional vehicles on a lifecycle cost basis. Our cost analysis concludes that in the 2003 time frame, both the initial and the lifecycle cost of battery electric vehicles will significantly exceed that of comparable conventional vehicles. In volume production (100,000 units per year), it is possible that battery electric vehicles could be competitive with conventional vehicles on a lifecycle cost basis.

The near-term cost premium is not surprising, given that each incremental step towards more stringent air pollution controls provides additional benefits, but at additional cost. The ZEV program, meanwhile, is not a typical incremental step but rather a visionary approach that will transform our vehicle pollution control strategy and bring with it comprehensive multimedia environmental and energy benefits. Given the sweeping nature of its effects it is reasonable to expect that the program will be more expensive in its early years than other more limited measures. Various means are available to close this cost gap. Ultimately, the decision as to what costs are reasonable and how they should be borne is a policy matter for the Board to determine.

The above three conditions are necessary to ensure successful implementation of the ZEV regulation. Other factors can ease the transition. As discussed in the EV market section, continuity between today and 2003 is vital. At the moment, however, there is a large gap between the completion of the MOA placements and the beginning of the 2003 requirement.

Finally, there will need to be teamwork among the interested parties who follow the ZEV issue. The auto manufacturers will benefit from the assistance of others. Areas where cooperative efforts would be helpful include the provision of incentives, development of the fleet market, and public education.

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APPENDIX A

EXECUTIVE SUMMARY,
DRAFT REPORT OF THE 2000 BATTERY TECHNOLOGY ADVISORY PANEL

Advanced Batteries for Electric Vehicles: An Assessment of Performance, Cost, and Availability

DRAFT

June 22, 2000

Prepared for
State of California Air Resources Board
Sacramento, California

By

The Year 2000 Battery Technology Advisory Panel

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DISCLAIMER

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EXECUTIVE SUMMARY

When the California Air Resources Board began to consider battery-powered EVs as a potentially major strategy to reduce vehicle emissions and improve air quality, it did so with the view that the broadest market would be served by electric vehicles with advanced batteries, and it structured its ZEV credit mechanisms to encourage the development and deployment of EVs with such batteries. Consistent with this view, the Air Resources Board defined the scope of work for the first Battery Technical Advisory Panel study to focus on advanced batteries.

Five years after the modification of the 1991 Zero Emission Vehicle regulation, and after a period of intensive effort to develop, deploy and evaluate advanced electric vehicles, one key remaining question is whether batteries can be available in 2003 that would make electric vehicles acceptable to a large number of owners and operators of automobiles. The answer to this question is an important input to the California Air Resources Board's year 2000 Biennial ZEV regulation review. The authors of this report were asked to assist ARB in developing an answer, working together as a new Battery Technical Advisory Panel (BTAP 2000).

The Panel concentrated its investigation on candidate EV-battery technologies that promise major performance gains over lead-acid batteries, appear to have some prospects for meeting EV-battery cost targets, and are now available from low-volume production lines or, at least, laboratory pilot facilities. In the view of the Panel, other types of advanced batteries not meeting these criteria are highly unlikely to be introduced commercially within the next 5-7 years. While the focus of BTAP 2000 like the first battery panel was to be on advanced batteries because of their basic promise for superior performance and range, ARB asked the Panel to also briefly review the lead-acid battery technologies used in some of the EVs deployed in California. This request recognized that EVs with lead-acid batteries were introduced in the 1990s by several major automobile manufacturers beginning with General Motors' EV1, and that EVs equipped with recently developed lead-acid batteries were performing significantly better than earlier EVs.

The Panel's approach was similar to that of the 1995 BTAP: visits to the leading developers of advanced batteries and to major automobile manufacturers engaged in electric-vehicle development, EV deployment, and in the evaluation of EV batteries; follow-on discussions of the Panel's observations with these organizations; Panel-internal critical review of information and development of conclusions; and preparation of this report. To assist the Panel members with the development of judgment and perspective, they were given business-confidential technical and strategic information by nearly all of the Panel's information sources. This report, however, contains unrestricted material only. The Panel's findings and conclusions are as follows.

The improved lead-acid EV batteries used in some of the EVs operating in California today give these vehicles better performance than previous generations of lead acid batteries. However, even these batteries remain handicapped by the low specific energy that is characteristic of all lead-acid batteries. If EV trucks or representative 4-5 passenger EVs could be equipped with lead-acid batteries of sufficient capacity to provide a practical range of 75-100 miles on a single charge, batteries would represent 50% or more of the total vehicle weight. The specific costs of these batteries produced in volumes of 10,000-25,000 packs per year are projected to be between \$100/kWh and \$150/kWh, about 30-50% of the cost projected for advanced batteries produced in comparable volume. On the other hand, the life of lead-acid batteries remains a serious concern because the high cost of battery replacement might well offset the advantage of lower first costs.

Nickel-metal hydride (NiMH) batteries, employed in more than 1000 vehicles in California, have demonstrated promise to meet the power and endurance requirements for electric-vehicle (EV) propulsion. Bench tests and recent technology improvements in charging efficiency and cycle life at elevated temperature indicate that NiMH batteries have realistic potential to last the life of an EV, or at least ten years and 100,000 vehicle miles. Several battery companies now have limited production capabilities for NiMH EV batteries, and plant commitments in 2000 could result in establishment of manufacturing capacities sufficient to produce the quantities of batteries required under the current ZEV regulation for 2003. Current NiMH EV-battery modules have specific energies of 65 to 70Wh/kg, comparable to the technologies of several years ago—reported in the BTAP 1995 report (1)—and major increases are unlikely. If NiMH battery weight is limited to an acceptable fraction of EV total weight, the range of a typical 4/5-passenger EV in real-world driving appears limited to approximately 75 to 100 miles on a single charge.

Despite extensive cost reduction efforts by the leading NiMH EV-battery developers, NiMH battery cost remains a large obstacle to the commercialization of NiMH-powered EVs in the near term. From the cost projections of manufacturers and some carmakers, battery module specific costs of at least $350/kWh, $300/kWh and $225-250/kWh can be estimated for production volumes of about 10k, 20k and 100k battery packs per year, respectively. To the module costs, at least $1,200 per battery pack (perhaps half of that sum in true mass production) has to be added for the other major components of a complete EV-battery, which include the required electrical and thermal management systems. On that basis, and consistent with the Panel’s estimates, NiMH batteries for the EV types now deployed in California would cost EV manufacturers between $9,500 and $13,000 in the approximate quantities (10k-

20k packs per year) required to implement the year 2003 ZEV regulation, and approximately $7,000 to $9,000 at production levels exceeding one hundred thousand packs per year.

Lithium-ion EV batteries are showing good performance and, up to now, high reliability and complete safety in a limited number of EVs. However, durability test data obtained in all major lithium-ion EV-battery development programs indicate that battery operating life is typically only 2-4 years at present. Li Ion EV batteries exhibit various degrees of sensitivity when subject to some of the abuse tests intended to simulate battery behavior and safety under high mechanical, thermal or electrical stresses. Resolution of these issues, the production of pilot batteries and their in-vehicle evaluation, and fleet testing of prototype Li Ion batteries meeting all critical requirements for EV application are likely to require at least three to four years. Another two years will be required to establish a production plant, verify the product, and scale up to commercial production. Based on several (albeit not all) of the cost estimates provided by developers and on the Panel's own estimates, these batteries will be significantly more expensive than NiMH batteries at a production volume of around 10,000 packs per year. Even in much larger production volumes, Li Ion EV batteries will cost less than NiMH only if substantially less expensive materials become available, and after manufacturing technologies combining high levels of automation, precision and speed have been developed.

Lithium-metal polymer EV batteries are being developed in two programs aimed at technologies that might cost $200/kWh or less in volume production. However, these technologies have not yet reached key technical targets, including most notably cycle life, and they are in the pre-prototype cell stage of development. It is unlikely that the steps required to achieve commercial availability of Li Polymer batteries meeting the performance and life requirements, as well as the cost goals for EV propulsion, can be completed in less than 7 to 8 years.

Battery developers, USABC, and the six major automobile manufacturers serving the California market have invested extensive financial and talent resources in developing a diversity of EV batteries and evaluating them in electric vehicles. Battery performance and reliability has been excellent in many, and generally adequate in nearly all, of the more than 1400 EVs deployed to date with advanced batteries, most of them of the NiMH-type. However, advanced battery costs will exceed by about $7,000 to $9,000 in the nearer term, and about $5,000 at automotive-mass-production levels, the cost goals derived for EV batteries by postulating comparable life-cycle costs for broadly comparable electric and ICE-powered vehicles.

These cost projections assume reductions arising from incremental technological advances as well as cost reductions resulting from the economies of scale of materials procurement and high-volume manufacturing. In the Panel's assessment, major technology advances or breakthroughs would be required to reduce advanced battery costs substantially below current projections; the Panel considered this unlikely for the next 6-8 years. In addition, the practical range provided by the batteries of current EVs is limited. For applications where increased range is desired, the resulting larger-capacity batteries would aggravate the advanced-battery cost problem in proportion, and they would raise increasingly serious volume and weight issues.

All major carmakers are now actively pursuing other advanced-technology vehicles—such as hybrid and mini EVs—to achieve emission reductions. Like conventional EVs, HEVs and mini-EVs depend on improved batteries for their technical and cost feasibility. However, they require only a fraction of an EV's battery capacity—between 5% and 50%, depending on HEV technology and application. Battery cost is thus substantially reduced, and thereby one of the largest barriers to the commercial viability of these new automotive products. The Panel was made aware of the impressive battery technology progress achieved in this area by several of the EV-battery developers. There is little doubt that the development of NiMH and Li Ion battery technologies for HEV and mini-EV applications has benefited directly and substantially from EV-battery development. Conversely, the successful commercialization of HEVs, and possibly mini-EVs, in the coming years can be expected to result in continued improvements of advanced battery technologies. Over the longer term, these advances—together with likely advances in electric drive technologies and reductions in vehicle weight—might well increase performance and range, and reduce costs, to the point, where electric vehicles could become a widely accepted product.