CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
AIR RESOURCES BOARD

STATUS REPORT ON THE CALIFORNIA AIR RESOURCES BOARD'S ZERO EMISSION VEHICLE PROGRAM

ZEV TECHnology Review

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1.0 Introduction

The goal of the Air Resources Board's (ARB or the Board) Zero Emission Vehicle (ZEV) program is to evolve the California passenger car fleet to vehicles with no direct emissions. Since its inception in 1990, the program has been modified on several occasions to better reflect the pace of technological development, costs and realities of the marketplace. The ZEV program continues to push the development of clean vehicles and supports the vision needed to meet California's longer-term environmental goals.

This report has been prepared in response to the Board's direction to staff at its April 2003 Board hearing. As described in Resolution 03-4, the Board directed that an independent panel of experts be appointed to report on the status of ZEV technologies and on the readiness of various technologies for market and consumer acceptance. The Independent Expert Panel's (Panel's) Report is attached as Appendix A. In addition to the information gathered by the Panel, data presented at an ARB ZEV Technology Symposium and other information collected by ARB staff are being made available to assist the Board in determining if further adjustments to the program are warranted.

To provide an understanding of the program's effectiveness in pushing research and development and the commercial potential of advanced vehicles, this report examines the key findings of the Panel, industry-wide compliance status, and the development of infrastructure necessary for vehicles in the ZEV program.

2.0 Background

In September 1990, ARB adopted a low-emission vehicle regulation whose aim is to drastically reduce pollution from passenger cars and light-duty trucks. As part of the newly created program, the Board included a goal of requiring large auto manufacturers to commercialize vehicles with zero emissions, beginning with 1998 model-year vehicles. This ZEV requirement was included to catalyze efforts to commercialize sustainable transportation. The program would ultimately have the added benefit of prompting manufacturers to develop extremely clean conventional and alternative fuel and hybrid electric vehicles.

Because of the long-term, technology-forcing nature of the ZEV regulation, the Board directed that staff provide regular updates on the progress being made in meeting the requirements. Doing so has given the Board the information necessary to amend the program to respond to new developments in vehicle technology and to the experiences gained by industry.

2.1 Current Program

The original ZEV program required that 10 percent of new vehicle sales by large manufacturers have zero emissions, starting with 1998 models. The Board modified the program in 1998 and 2001 to allow up to 60 percent of the requirement to be met with vehicles having extremely low emissions and specific attributes, as shown in Table 2.1. In 2009 up to 85 percent of the requirements may be met with these vehicles. Vehicles meeting these standards are referred to as "partial zero emission vehicles" (PZEV) and "advanced technology partial zero emission vehicles" (AT PZEV). Staff refer to the categories of vehicles used to meet the ZEV regulation as gold (ZEV), silver (AT PZEV) and bronze (PZEV) to simplify discussion. PZEVs and AT PZEVs have achieved commercial success and are responsible for significant emissions reductions due to the large numbers of vehicles sold. Examples of a PZEV are the Ford Focus and BMW 325. An example of an AT PZEV is the Toyota Prius hybrid electric vehicle.

Table 2.1
ZEV Program Requirements
2009 Model Year - Base Path

Certification Standards				
% Requirement	% of Total Vehicle Sales[1]	Vehicle Type	Category	Technical Description
2.5%	< 1%	Zero Emission Vehicle (ZEV)	Gold	Zero tailpipe emissions: battery electric vehicles, and hydrogen fuel cells.
2.5%	5%	Advanced Technology (AT PZEV)	Silver	Vehicles certified to PZEV standards and employing ZEV-enabling technologies: e.g. hybrids or compressed natural gas vehicles.
6%	30%	Partial Zero Emission Vehicle (PZEV)	Bronze	Conventional vehicles certified to the most stringent tailpipe emission standards, zero evaporative emissions, and extended warranty.
11%	Total ZEV Requirement			

1. Percent of total California sales differs from percentage requirement because credits per vehicle type vary.

The Board's most recent amendments to the ZEV program in 2003 revised the percentage of ZEVs required to 11 percent starting in 2009, increasing to 16 percent in 2018. Large volume manufacturers are allowed to comply with either the base compliance path using the percentage ZEV requirements shown in Table

2.1, or with an alternative path, shown in Table 2.2 below. The Alternative Path is designed to advance the commercialization of fuel cell vehicles[1]. It allows AT PZEVs to be used to meet both the gold and silver obligations, provided that the manufacturer meets the requirements specified below.

Table 2.2
Alternative Compliance Path Fuel Cell Requirements

Phase	During Model Years	Manufacturer's Market Share of:
I	2005 to 2008	250 fuel cell vehicles
II	2009 to 2011	2,500 fuel cell vehicles
III	2012 to 2014	25,000 fuel cell vehicles
IV	2015 to 2017	50,000 fuel cell vehicles

As illustrated in Table 2.2, the requirement for fuel cell vehicles increases by a factor of ten for Phase II and III and then doubles for Phase IV, reflecting a transition from demonstration to full commercialization. Phases I and II reflect that fuel cell vehicles are still early in the development process, with further technological changes expected prior to ramp-up toward commercialization. Phases III and IV are designed to establish new commercial markets for the technology in California. A central task assigned to the Panel was to determine if the Alternative Path is technologically feasible and appropriate to achieve successful fuel cell commercialization.

2.2 Manufacturer Actions and Compliance

Manufacturers originally planned to meet the ZEV requirements with battery electric vehicles. In 1996, due to cost and performance issues, the ARB eliminated the early (1998) requirements to allow additional time for battery research and development. To ensure a significant market for advanced battery manufacturers, the ARB entered into agreements with manufacturers to place in California roughly 1,800 advanced-battery electric vehicles between 1998 and 2000. The agreements were designed to provide battery developers with the necessary initial production volumes to meet the cost and performance goals needed for commercial production. Contrary to expectations, the cost for advanced batteries remained too high for commercial viability. In 2003, the Board found that nickel metal hydride battery packs for full function electric vehicles would cost approximately $7,000 to $9,000 each at production levels exceeding 100,000 battery packs per year, and would cost two times more at lower production levels. Notwithstanding these costs, several manufacturers continued

[1] The Alternative Path requires use of Type III ZEVs. Type III ZEVs are defined as ZEVs with driving range greater than 100 miles and the ability to refuel in 10 minutes or less. This requirement is currently demonstrated by fuel cell vehicles, therefore, when referring to the regulation requirements related to Type III ZEVs, staff refers to fuel cell vehicles.

to place a modest number of battery electric vehicles beyond the memorandum of agreement volumes. These vehicles earned ZEV credits that have been used for compliance with the regulation.

Manufacturers began to look seriously at hydrogen fuel cell vehicles in the late 1990’s as an alternative to battery electric vehicles. This interest led to cooperative efforts among the ARB, industry and other governmental agencies to create the California Fuel Cell Partnership (Partnership) in 1999. The goals of the Partnership are to demonstrate vehicle technology and the viability of hydrogen fuel infrastructure technology, explore paths to commercialization, and increase public awareness and enhance opinion about fuel cell electric vehicles. Manufacturers continue to aggressively pursue the development of fuel cell vehicles.

There are currently twenty-one auto manufacturers subject to the ZEV regulation. Six are defined as large volume manufacturers: General Motors, Toyota, Ford, Honda, DaimlerChrysler and Nissan. The remaining 15 are intermediate volume manufacturers. Intermediate manufacturers can meet the regulation entirely with PZEVs.

All manufacturers are currently in compliance with the ZEV regulation. Most manufacturers have enough banked credits from zero emission vehicles already placed to comply with the regulation through approximately 2009. One manufacturer has produced more fuel cell vehicles than required to meet their Alternative Path obligation for 2005 to 2008. The remaining manufacturers have, on average, completed about half their production obligation. It should be noted however, that while all of the large manufacturers have active fuel cell vehicle demonstrations, some of these manufacturers may chose to comply using the Base Path and would not need to produce any additional fuel cell vehicles between now and the end of 2008.

To meet the AT PZEV requirement, some large manufacturers are producing AT PZEVs (primarily hybrid electric vehicles) and some large manufacturers are using previously produced neighborhood electric vehicle credits. Four of the six large manufacturers have AT PZEVs in the market; two of these manufacturers, Toyota and Honda, dominate the volumes produced to date. Most of the large manufacturers have sufficient banked credit to more than meet the AT PZEV requirement for several years to come. Regardless of the method with which manufacturers are meeting the AT PZEV requirement, the number of AT PZEVs produced to date is beyond what is required by the ZEV regulation. For example, in 2005, twice as many AT PZEVs were produced than required to meet AT PZEV requirements. That will change towards 2009, when the required volume of AT PZEVs increases to 8 percent of the total fleet. The Panel was asked whether the required volumes of AT PZEVs are in line with ARB’s ZEV deployment strategy.

Table 2.3 presents the approximate total number of gold, silver and bronze vehicles placed as of model-year 2005. Manufacturers have been producing PZEVs at a rate greater than their obligation in aggregate. For example, in 2005, manufacturers on the whole produced 40 percent more PZEVs than the industry wide PZEV requirement.

Table 2.3
Vehicle Placements by Type
(Through 2005)

Vehicle Type		Quantity[1]
ZEV	Fuel cell	130
ZEV	Battery electric	4,400
ZEV	Neighborhood electric	26,000
AT PZEV	Hybrid/Compressed Natural Gas	70,000
PZEV	Conventional	507,000

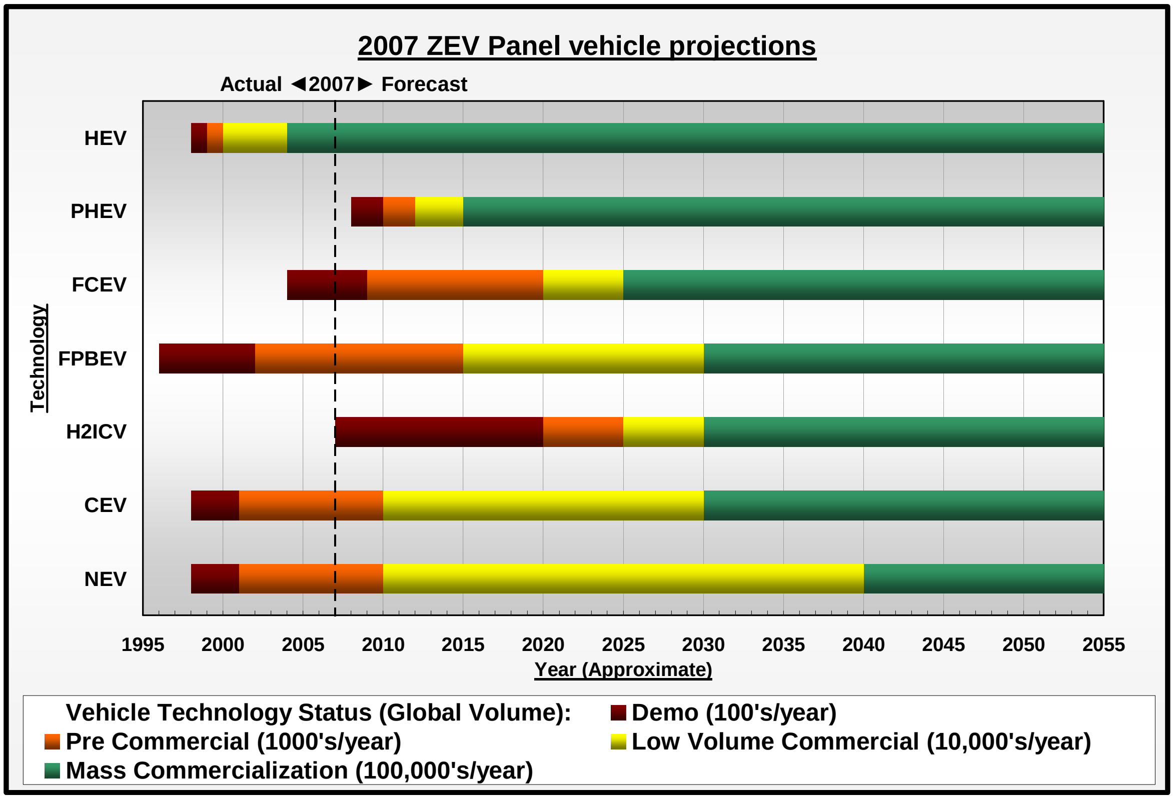
1 Estimates of total vehicle placements from 1994 through 2005

3.0 Summary of Expert Review Panel Findings

The Expert Review Panel was asked to provide a thorough and accurate assessment of the current worldwide status of zero emission vehicle technologies and the prospects for technology advancement in both the near- and long-term. In addition, the Panel was asked to project mass marketability of vehicles using these technologies. Finally, the Panel was also asked to evaluate the synergy between the AT PZEV requirements and the development of ZEV technologies.

The Panel spent much of 2006 gathering technical information, cost data, and expert opinions from leading developers of components and major manufacturers through correspondence and site visits. The information was then critically assessed by the Panel to project the current status and prospects for commercialization of each of the technologies evaluated. Figure 3.1 below illustrates the Panel's projections of when various ZEV technologies will be ready for demonstration and increased volumes along the path to commercialization.

Figure 3.1
Projected Achievement of Global Volumes



1. "HEV" means hybrid electric vehicle; "PHEV" means plug-in hybrid vehicle; "FCEV" means fuel cell electric vehicle; "FPBEV" means full performance battery electric vehicle; "H2ICV" means hydrogen internal combustion vehicle; "CEV" means city battery electric vehicle; "NEV" means neighborhood battery electric vehicle.

Following are summaries of the Panel's findings by technology type.

3.1 Fuel Cell Electric Vehicles

As shown in Figure 3.1 above, the Fuel Cell Electric Vehicle (FCEV) bar lines up fairly closely to the Alternative Path volumes listed in Table 2.2 for the start of Phase II. However, the Panel's estimate for transition to 10,000s of vehicles is 2020, compared to the current ZEV Alternative Path Phase III date of 2012.

The Panel found that FCEVs are considered by several manufacturers to be the ultimate solution to reducing both criteria pollutant and climate change emissions. Most major manufacturers have made significant investments in research, development, and demonstration of the technology. While substantial progress has been made, simultaneously achieving performance, durability and cost objectives continues to be a difficult challenge. In addition, the cost, weight, and volume of adequate on-vehicle hydrogen storage and availability of hydrogen production and infrastructure remain major barriers to commercialization. Table 6.1 in Section 6 of this report summarizes the Panel's key technology and cost projections.

The Panel concluded that while these challenges are not trivial, the past rate of success and the massive intellectual and financial resources being devoted to fuel cell vehicle technology, ensures that FCEVs remain a promising candidate for a future mass market true ZEV.

3.2 Battery Electric Vehicles

The Panel found that previous efforts to commercialize battery electric vehicles prompted by the ZEV program were unsuccessful due to cost and lack of mass market customer acceptance. They also found that in other countries where fuel prices and driving conditions provide lower barriers to commercialization, a few manufacturers are now developing smaller vehicles using lithium-based batteries. However, the Panel concluded that in California, full-sized battery electric vehicles are still not likely to be a mass market technology in the foreseeable future due to high cost of the batteries, and limited customer acceptance. The Panel concluded that city electric vehicles are more likely to become future mass market ZEVs in Japan and Europe than in the United States due to performance limitations and vehicle safety requirements.

3.3 Plug-in Hybrid Electric Vehicles

The Panel found that plug-in hybrid electric vehicles offer direct societal benefits to the consumer and are likely to become commercially available in the near future. The incremental cost of the small battery pack should be offset by the lower operating cost of the technology. The major technical issue with PHEVs is the ability of the energy battery to endure the large number of deep cycles the battery must deliver over the life of the vehicle. The number of deep cycles is substantially higher for PHEVs than FPBEVs and thus represents a new dimension in deep cycling requirements. Battery cycle life for PHEVs is not completely know at this time. The Panel also found that test procedures to accurately determine emissions and efficiency do not exist and need to be developed. Also, the cost impact of greater electric range is not well understood and could have a significant impact on consumer acceptance. The Panel concludes that commercialization of plug-in hybrid electric vehicles will stimulate battery development and help consumers become comfortable with plugging in a vehicle.

3.4 Hydrogen Internal Combustion Engines

The Panel found that manufacturer interest in the use of hydrogen internal combustion engines is not widespread. While developing conversions of conventional powertrains is far easier than fuel cell vehicles, issues regarding hydrogen storage and infrastructure are the same or worse than those facing fuel cell vehicles.

The Panel found that while the technology is not true zero emissions, prototype vehicles have demonstrated very low emissions. The technology also provides minor benefits to future mass market ZEVs by increasing demand for a refueling infrastructure and fuel supply.

3.5 Advanced Technology Partial Zero Emission Vehicles

The Panel found that the ZEV program requirements for AT PZEVs, particularly hybrids, help to develop pure ZEV technologies by accelerating the development and deployment of advanced ZEV technologies. In particular, key systems contained within the hybrid systems are directly comparable to key ZEV fuel cell systems. These include efficient electric drive motors, high power electronics, and computer control systems which incorporate regenerative braking. Promoting the widespread adoption of these technologies in AT PZEVs will lead to performance improvements and cost reductions that are necessary for ZEVs to become mass-market vehicles in the future.

The Panel also found that the research and development work on hybrid batteries by manufacturers, battery suppliers, and material developers worldwide, continues to improve the key characteristics of batteries used in hybrid applications. The Panel concluded that this in turn will improve the batteries needed in future pure ZEV technologies, including fuel cell vehicles and battery electric vehicles.

The Panel found that hybrid technology appeals to the mass market customer willing to pay a premium. The Panel concluded that production of hybrid electric vehicles (HEV) continues to reduce the cost of electric drive components and systems - but cost is still an issue and future market success and volume of HEVs is largely dependent on the price of gasoline – making future growth uncertain.

3.6 Neighborhood Electric Vehicles

The Panel found that over the last several years, a limited market for neighborhood electric vehicles appears to have had some commercial success. However, they concluded that the mature market potential for the technology is relatively small due to limited applicability. Neighborhood electric vehicles represent a very simple technology and have little synergy with larger battery electric vehicles. As such, the Panel concluded that neighborhood electric vehicles provide no significant benefits to future mass market ZEVs due to simple technology and performance limitations. On the positive side, NEVs serve a particular market quite well and there are no barriers to deployment.

4.0 ZEV Technology Symposium

In September 2006, the ARB staff held a 2 ½ day ZEV Technology Symposium to gather additional information from industry, academia, and the public. Sessions included:

- Background information on the ZEV regulation
- Updates from the auto manufacturers
- Hydrogen technology
- Battery technologies
- Battery electric and plug-in hybrid electric vehicle demonstrations

An open comment session allowed the public to provide additional presentations and perspectives.

Symposium session information provided staff with useful technology updates. The hydrogen technology session covered current hydrogen storage capability (liquid versus gaseous hydrogen), fuel cell technology developments, hydrogen powered combustion engine development, and hydrogen infrastructure requirements. New small volume vehicle manufacturers provided information on their development of battery electric vehicles while battery developers provided an update on lithium ion technology and testing methods. Large volume manufacturers provided an update on upcoming vehicle platforms, while supporters of electric and plug in hybrid electric vehicles provided their perspective on new emerging technologies.

The following general findings were gleaned from the Symposium presentations:

- Fuel cell development is progressing with newer generations of technology, but higher pressure hydrogen storage systems are needed to increase vehicle range, and overall system cost is still a concern.
- Lithium ion battery technology is showing promising development results for plug-in hybrid electric vehicles and extended all-electric driving range, but further material and battery production research is still needed.
- Further testing results on battery durability and cycle life are also needed.
- Low volume battery electric vehicle manufactures' will begin production in the near term, helping to push new battery electric vehicle technologies into the California market.

5.0 Fueling Infrastructure Status

An important part of successful commercialization of ZEVs is refueling infrastructure. The staff did not ask the Panel to report on infrastructure readiness in light the California Hydrogen Highway Network's Blueprint Plan for implementation of hydrogen refueling stations. The findings of the Blueprint Plan and an update on implementation are presented below.

Concerning battery electric vehicles, significant public infrastructure was installed to recharge these vehicles over the last 15 years. Any future production of battery electric vehicles will benefit from the lessons learned and the infrastructure to recharge the vehicles will be much easier to establish.

5.1 California Hydrogen Highway Blueprint Plan

The Blueprint Plan for the establishment of a Hydrogen Highway Network was created at the direction of the Governor in Executive Order S-7-04. The Executive Order directed state agencies to work with industry and academic partners to agree on the best way forward to create the infrastructure necessary to support introduction and broad commercialization of hydrogen vehicles. The Blueprint Plan was developed with the help of over 200 industry, academic and government experts over the course of a year. In May of 2005, the Blueprint Plan was released with the following findings:

- The number and location of stations should closely match deployment of vehicles to avoid under utilization of stations or stranded vehicle demonstrations. In particular, the largest urban areas of the State were selected as target locations for early mini networks; Los Angeles, San Diego, San Francisco and Sacramento. The Blueprint Plan suggested that 50 to 100 stations in 2010 could support at least 2,000 hydrogen vehicles.
- Environmental goals for well-to-wheel performance of hydrogen vehicles are important. The Blueprint plan recommended that emissions of greenhouse gases be reduced 30 percent and that criteria pollutants and toxic emissions not be increased compared to conventional vehicles. The Blueprint Plan also recommended that hydrogen be produced from a minimum of 20 percent renewable resources.
- Industry, academia and government need to share the risk. It is appropriate for all sectors to partner to coordinate implementation and to share the development and financial burdens of creating the hydrogen refueling network. Accordingly, the Blueprint Plan recommendation that the State co-fund placement of hydrogen stations and provide subsidies for hydrogen vehicles.

5.2 Implementation Status

Attached as Appendix B is the California Hydrogen Highway Network's Year End Progress Report to the Legislature summarizing the progress of infrastructure development in California. Currently, there are 24 hydrogen fueling stations operating in California and 11 more in the planning or development stages. Of the 24 existing stations, 15 are "publicly" accessible. The other nine stations are private, serving a restricted fleet of vehicles. The existing hydrogen stations have been developed and funded through a variety of collaborative, public-private partnerships that include the U. S. Department of Energy, local air quality districts and State government.

Manufacturers are still concerned that infrastructure will be insufficient in the short term to meet the needs of their next generation vehicle placements. While approximately five new hydrogen stations will come on line over the next year, and six additional stations are planned, California is far shy of the 50 to 100 station goal recommended in the Hydrogen Blueprint Plan for 2010. Co-funding and other incentives, in addition to mitigating liability and solving codes and standards issues, will be critical priorities to continue the development of a hydrogen refueling network.

6.0 Program Policy Implications

The Panel was not asked to make recommendations regarding the ZEV regulation. They were asked only to provide the technical basis for the Board to assess the progress and potential for success of the ZEV technologies. In the following section, staff reviews fundamental issues and questions relevant to implementation of the ZEV program, and identifies where changes to the program may be needed.

6.1 Fuel Cells

Issue: In 2003 it was clear that the Board wanted to accelerate development and commercialization of fuel cell vehicles. Creating the Alternative Path provided an incentive to manufacturers to aggressively demonstrate fuel cell vehicles in California in phases designed to lead to mass commercialization. However, when the Board approved the ramp up schedule for the Alternative Path there was a wide divergence of opinion about how and when a commercialization ramp up would take place. This was one of the primary reasons the Board asked the staff to convene an Independent Expert Panel. The Board wanted to know, once initial demonstrations were launched, what the prospects for volume growth would be.

Current Treatment in the Regulation: Table 2.2 of this report shows the ramp up schedule for fuel cell vehicles in the Alternative Path, with a ten times increase in volume for each phase of implementation until Phase IV when it doubles. Based on discussions with manufacturers and looking at the U. S. Department of Energy's (U.S. DOE's) estimates of anticipated technology development and introduction, this approach appeared reasonable in 2003.

Panel Findings: "The intense effort on FCEVs will result in technically capable vehicles by the 2015 to 2020 timeframe, but successful commercialization is dependent on meeting challenging cost goals and the availability of an adequate hydrogen infrastructure." Table 6.1 below taken from the Panel report summarizes the technical and cost status of fuel cell vehicles compared to the U.S. DOE's FreedomCar targets for commercialization.

Table 6.1
Derived from Table 6-10 from Panel Report
U.S. DOE's FreedomCAR Fuel Cell Power System1 Goals and Status

		Panel's Assessment of	
Fuel Cell Power System Parameter[1]	**FreedomCAR Goals** 2010/2015[2]	**Present Status**	**Forecasted 2015 Status**
Life (years)	15	2 – 3	10 – 13
Peak Efficiency (%)	60	50 – 60	60
Gravimetric Power Density[3] (W/kg)	325	300 – 500	700 – 1100
Volumetric Power Density[3] (W/l)	220	n/a	n/a
Cost[4] ($/kW)	$45 (2010) $30 (2015)	$75 – 600	$30 – 75

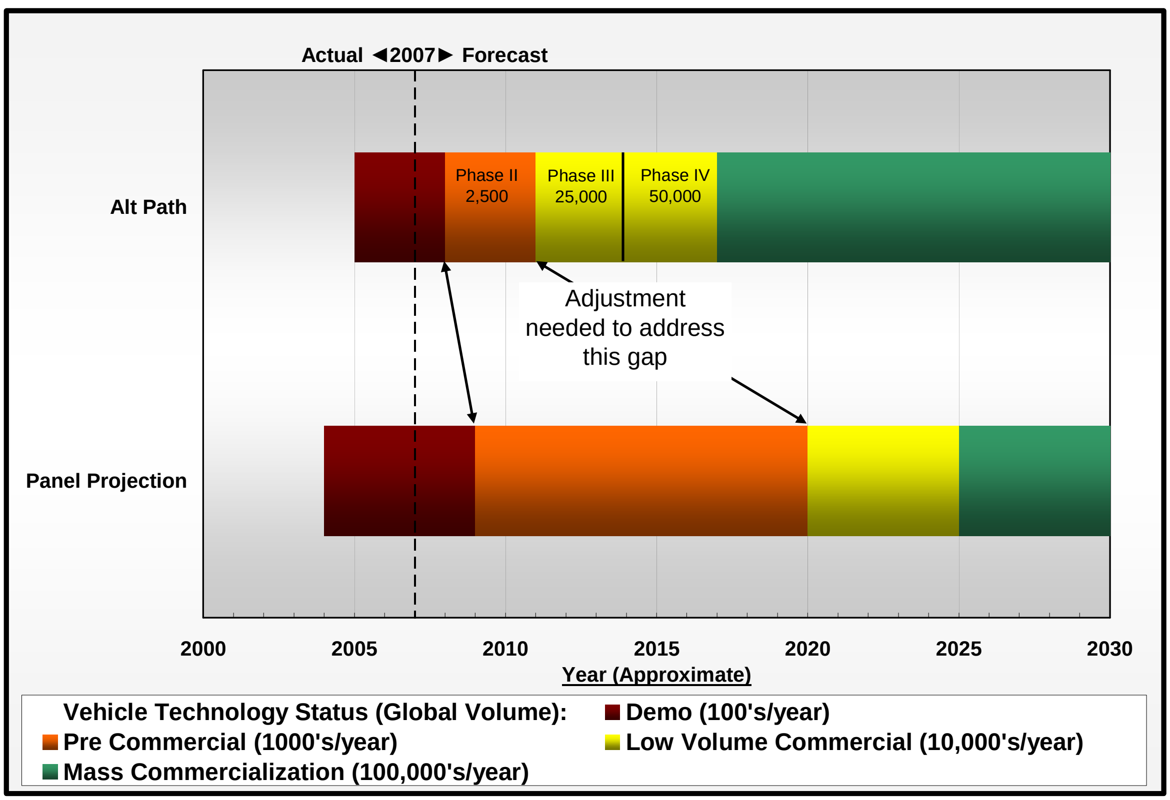
1. Consists of the fuel cell stack, the fuel cell stack auxiliary sub-systems (e.g., sub-systems for air supply, fuel supply, thermal management, and any other necessary functions, such as water management), the hydrogen storage system, the high voltage energy storage system (if used), and all enclosures and connections.
2. Source: Figure 3 (page 10), Technology-Specific 2010 and 2015 Research Goals, FreedomCAR and Fuel Partnership Plan, U.S. Department of Energy, March 2006, http://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/fc_fuel_partnership_plan.pdf
3. Excluding hydrogen storage.
4. Direct material/labor and production facility costs. Indirect costs, marketing and profit not included. Design level assuming 250,000 units per year.

As Table 6.1 shows, a number of targets are far from realization. In particular, the fuel cell life and cost remain far from targets that are necessary to achieve volume ramp-up. The Panel also identified hydrogen storage as a significant challenge to fuel cell vehicle commercialization for primarily cost reasons, and hydrogen infrastructure as perhaps the most significant barrier on the vehicle placement side of the equation.

Staff findings and recommendations: The fuel cell life issue alone points to the need for additional generations of fuel cell vehicles in limited numbers before ramping up to production volumes. Coupled with high per vehicle costs the need for further demonstration is undeniable. Staff, therefore, recommends that the Board adjust the Alternative Path phases to allow further demonstrations for continued progress towards the fuel cell stack life and cost goals.

The Panel projects that 1,000s of fuel cell vehicles per year globally are achievable in the next five years given the pace of efforts underway by manufacturers and suppliers. Staff concludes that the Phase II volumes, therefore, are appropriate (2,500 over three years, 2009 through 2011). Maintaining Phase II is especially important as manufacturers struggle to engage hydrogen fueling partners to seriously respond to the need for infrastructure (more utilization of stations catalyzes fuel provider investment). Where the Alternative Path deviates from the Panel's projections for commercialization is in Phase III, as illustrated in figure 6.1 below.

Figure 6.1
Fuel Cell Commercialization Forecast Compared to Alternative Path



As shown in this chart, the Panel's findings suggest that the transition from Phase II to Phase III is the area where adjustments are most needed. Such changes could range from repeating the volumes required in Phase II through addition of a Phase that would create an intermediate step between 2,500 and 25,000 vehicles.

Another approach could be to lengthen phases. An important consideration will be what volumes are necessary to cause investment in continuous manufacturing process development, a necessary step toward cost reduction.

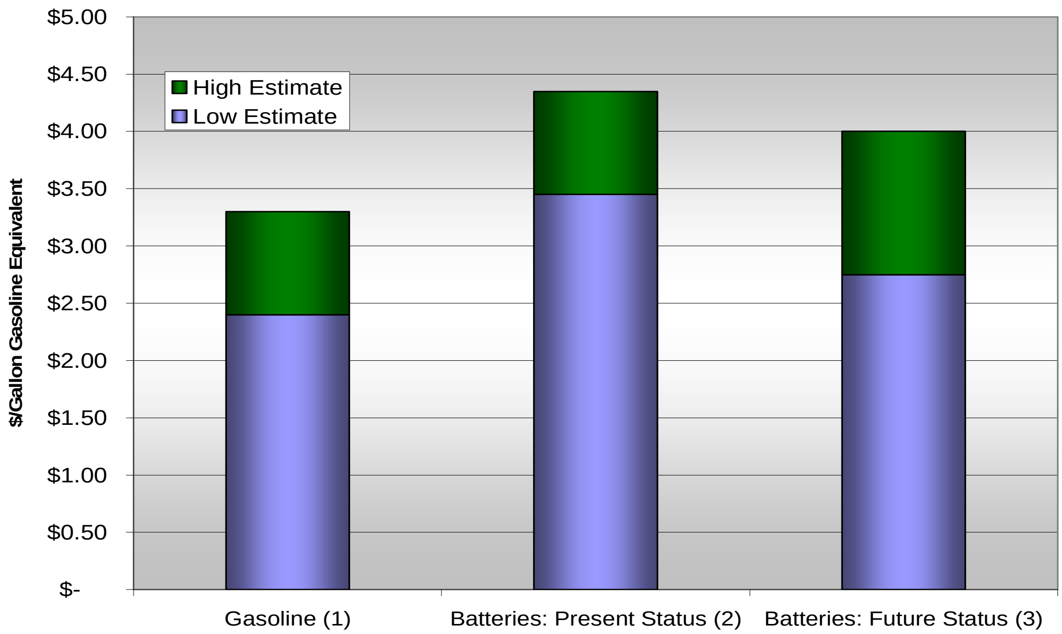
6.2 Battery Electric Vehicles

Issue: Battery electric vehicles (BEV) were the primary compliance strategy of manufacturers in the early years of the ZEV regulation's history. In 2003 however, the technical findings on cost and durability pointed to a limited opportunity to make BEVs mainstream. In an effort to refocus the regulation towards a technology with mass market commercial potential, the Board shifted the regulation towards acceleration of fuel cell vehicle technology. However, ARB's interest in BEV technology remains strong and staff is optimistic that BEV technology will play a significant role in California's future fleets.

Current Treatment in the Regulation: Battery electric vehicles can be used to meet the gold obligation in the ZEV regulation. The credit earned by a BEV depends on its driving range. However, because they cost much less than fuel cell vehicles (about 10^{th}), BEVs may only be used to meet up to half of the Alternative Path obligation and they may substitute for a fuel cell vehicle at a rate of ten to one (assuming full function BEV).

Panel Findings: The Panel found that progress has been made in batteries that could be used for BEVs. Both Nickel Metal Hydride (NiMH) and Lithium Ion (Li Ion) battery chemistries appear to provide performance and life cycle performance necessary for customers. However cost remains an issue. Figure 6.2, derived from the Panel's Table 6-4 illustrates one way of looking at the cost of the battery pack as a consumer might see it.

Figure 6.2
Comparison of Gasoline Price and
Battery Cost



(1) Retail gasoline price estimates are high and low for California from April 2006 through April 2007 according to California Energy Commission's website: http://www.energy.ca.gov/gasoline/graphs/diesel_images/image_grabber.php?link=Gas_Retail.gif
(2) Battery cost comparison assumptions: 10 year life, 12,000 miles/year, 27.5 mpg (combined) ICE vehicle, 0.300 kWh/mile AC basis for full function BEVs; costs not included: scheduled maintenance, battery markup and warranty cost not recovered by OEM, time value of money, inflation, value of vehicle at end of 10 years. 2006 average U.S. residential electricity rate of $0.0973/kwh. Battery pack cost source: Table 6-3 (U.S. Advanced Battery Consortium Goals for Electric Vehicle Batteries, 2005 Annual Progress Report, Energy Storage Research and Development, FreedomCAR and Vehicle Technologies Program, U.S. Department of Energy, January 2006).
(3) Future Status derived from Table 3-13 of Panel Report, assumes Lithium Ion batteries at 20,000 to 100,000 full-function BEV packs per year.

Figure 6.2 shows only what the cost of gasoline would need to be to make the incremental cost of the battery for a BEV cost comparable for the owner. This comparison assumes that the only difference in cost between a gasoline car and the BEV is the battery pack and it assumes that the owner is driving the vehicle 12,000 miles per year (which could be considered aggressive for a BEV).

The Panel also laid out information about several independent manufacturers with plans to market full function BEVs as well as the plans of several large and intermediate manufacturers to produce smaller city type BEVs for international markets where fuel costs and driving conditions support such urban commute vehicles.

Staff findings and recommendations: Battery electric vehicles have received renewed interest since 2003. Announcements by several new companies and improvements in battery chemistry have raised new optimism that the technology may be viable in the mid-term. Although the Panel notes that cost and utility are still significant barriers to full commercialization, staff recommends that the Board examine more even treatment of BEVs in the regulation as compared to FCEVs. For example, BEVs and FCEVs could offered equal credit before 2012. By returning to technology neutrality and considering BEVs and fuel cell vehicles similarly, the ARB might induce some manufacturers to choose to pursue battery electric vehicle development instead of fuel cell vehicle development. The outcome would be that overall ZEV production could be greater, but fewer fuel cell vehicles may be produced.

6.3 Plug-In Hybrid Electric Vehicles

Issue: The question of how to treat plug-in hybrid electric vehicles (PHEVs) was a controversial topic during the 2003 amendments and remains so today. The Board was asked to classify PHEVs as "gold" as they appeared to have greater chance for near term commercial viability considering the smaller battery pack, unlimited range and limited infrastructure needs. However, the Board said no, gold means zero emissions. Instead, the Board directed staff to create sufficient regulatory incentive outside of the gold category to encourage introduction of PHEVs. One of the toughest questions the Board asked the manufacturers as they testified at the 2003 hearings was "why don't you produce a plug-in hybrid vehicle?" Coming into this technology review, with still no PHEV from a major manufacturer, staff asked the Panel to help staff to assess what more could be done to further support PHEV.

Current Treatment in the Regulation: PHEVs earn silver credit that ranges from 10.8 to 18 depending on the amount of all electric range. This compares to a conventional hybrid that earns a credit of up to 0.7. PHEVs produced after 2009 may earn up to 4 credits each and after 2012 three credits each. Certification test procedures for PHEVs need revisions to better reflect current design approaches to PHEVs. When the initial certification procedures were adopted staff anticipated that PHEVs would be designed to operate in an all electric mode until the battery pack was exhausted. Instead, manufacturers are designing fully integrated PHEVs where the battery and gasoline engine operate intermittently or simultaneously (blended) throughout typical driving. Currently, the regulation invites manufacturers to present an alternative certification calculation method for approval of their PHEV system.

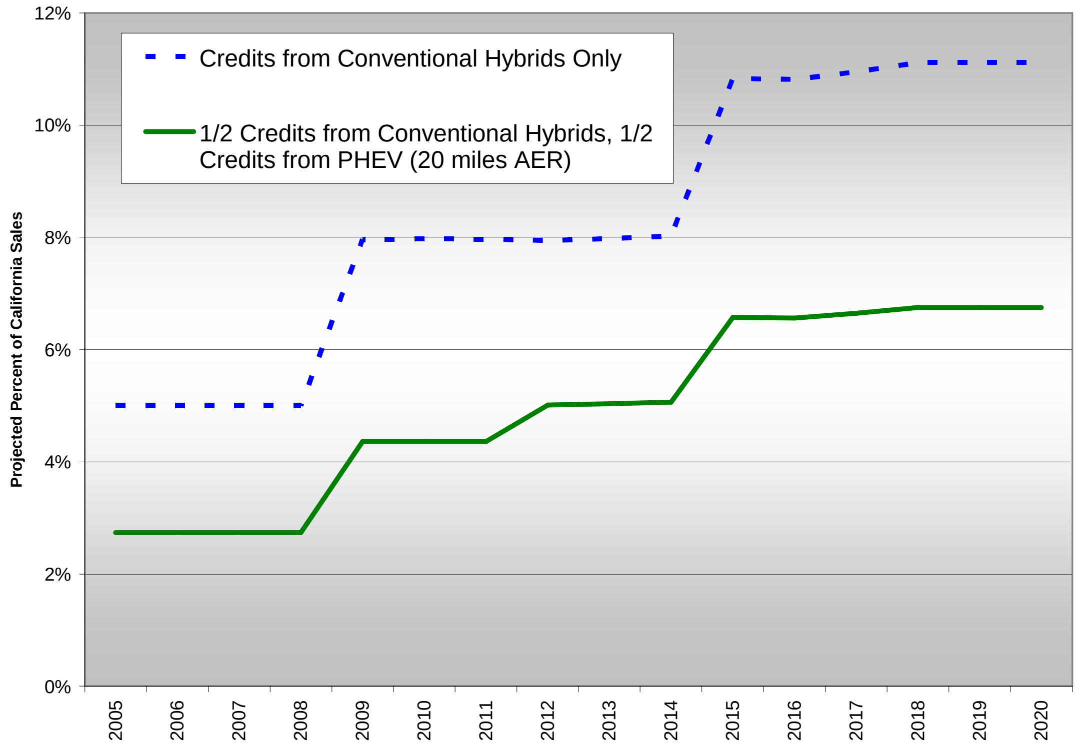
Panel Findings: The Expert Panel concludes that PHEVs have the potential to provide significant direct benefits and to foster future mass market ZEVs by stimulating battery development and conditioning mass market customers to accept plugging in. Several major manufacturers are showing a new interest in the technology and have recently announced PHEV development activities and timeframes for selling them to the public. PHEVs have the potential to achieve significant electric drive use. The technology may be very close to technical and economic feasibility and ready for mass market introduction by 2015. The Panel concluded that the significant issue that must be addressed before commercialization can take place is the cycle life of batteries used in PHEVs which may experience more deep cycles than full function BEVs.

Staff findings and recommendations: While interest in and technical promise for PHEVs is at an all time high, the fundamental question remains; should PHEVs count toward meeting pure ZEV requirements? Staff recommends against allowing PHEVs to be used in the gold category. This recommendation is based on the original concern that PHEVs are not zero emission. Additionally, uncertainty exists regarding how PHEVs will be used (will they be plugged in consistently and throughout their life? Will all electric range be maximized under a wide variety of driving cycles? etc.).

As examples of PHEVs are demonstrated it is clear that multiple approaches are under development that could have very different impacts on air quality. Traditionally, we have thought of plug-in hybrids as range extended battery electric vehicles or electric vehicles with an engine that could recharge the battery if/when needed. However, PHEVs being discussed today have more of a blended approach to using the battery pack. Like a conventional hybrid, the battery is used off and on throughout the driving cycle to assist the engine or drive in an all electric mode. Staff needs to learn more about how these blended PHEV strategies would be implemented and how they might impact air quality before recommending how they be treated in the ZEV regulation. For these reasons, staff does not recommend opening up the pure ZEV category as an incentive to bring PHEVs to market.

Staff does believe, however, that there are good reasons why manufacturers will produce PHEVs and there are adjustments to the regulation that could be explored that would facilitate this. The gold category is challenging for manufacturers, but as the percentage of the overall obligation that can be met by silver category vehicles increases, significant pressure builds on manufacturers to produce large numbers of “conventional” AT PZEVs. This pressure would make production of a high scoring silver vehicle increasingly attractive. Figure 6.3 illustrates an example of how use of PHEVs with 20 miles all-electric range to meet one half of the credits from the AT PZEV category can significantly reduce the overall number of AT PZEVs needed while creating a market for PHEVs.

Figure 6.3
Example PHEV use in AT PZEV Obligation
(Alternative Path example presented)

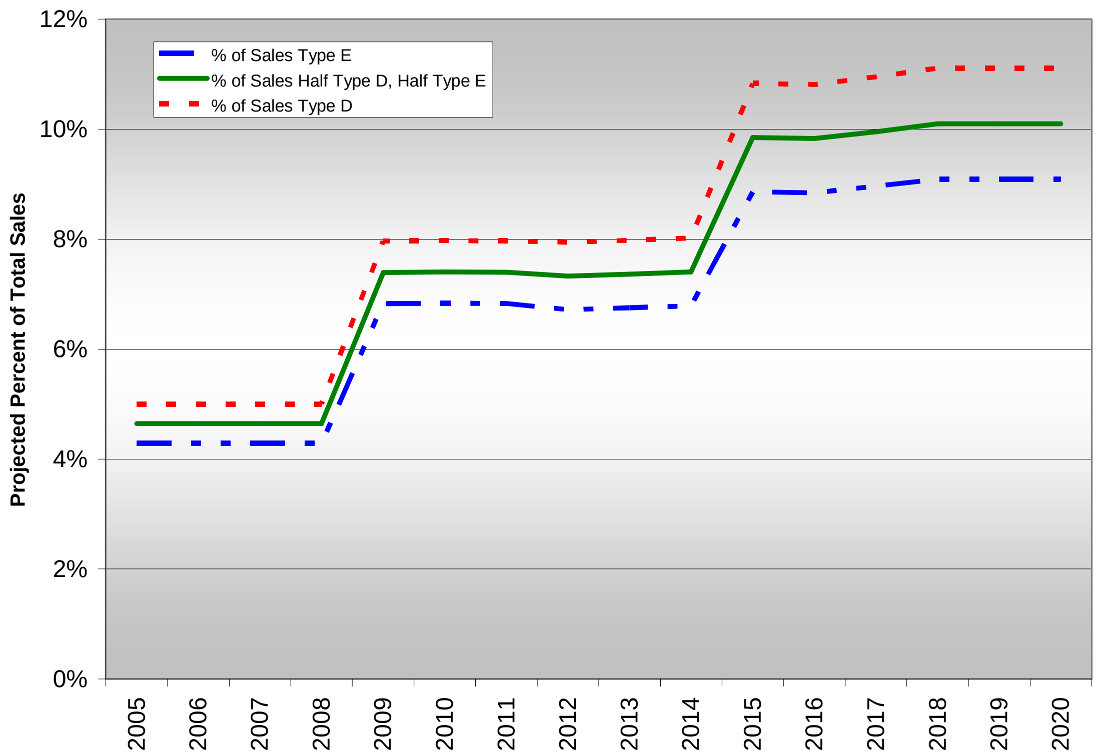


As figure 6.3 demonstrates, the percentage of vehicles that would be produced using only conventional hybrids reaches 11 percent of overall sales. However, meeting half of the silver category with PHEVs with all electric range of 20 miles reduces the obligation by about 40 percent with a maximum silver category volume reaching 7 percent of total sales. This pressure relief offered by PHEVs is significant and may be adequate incentive for their market introduction.

6.4 Advanced Technology Partial ZEV (AT PZEV) Volumes

Issue: The AT PZEV category was created to promote early commercialization of vehicle components that are instrumental to the success of zero emission vehicles, such as batteries, electric drive systems and hydrogen storage tanks. The way in which the regulation ramps up vehicle requirements over the years leads to relatively high volumes of AT PZEVs. Figure 6.4 illustrates how the volume of AT PZEVs grows if only conventional hybrids are used to comply with the AT PZEV category. Three cases are presented using different hybrid types; strong hybrids (Type E), moderate hybrids (Type D) and a mix of the two types.

Figure 6.4
AT PZEV Volumes Compared to All California Sales
(Alternative Path Example)



At the peak of implementation, AT PZEVs could account for 11 percent of projected total annual California vehicle sales. Manufacturers have argued that such volumes of AT PZEV technologies are not valuable to commercialization of ZEV components and that market acceptance of that volume of vehicles will be challenging. The Board directed that the Panel examine the value of high AT PZEV volumes to the development and commercialization of ZEVs.

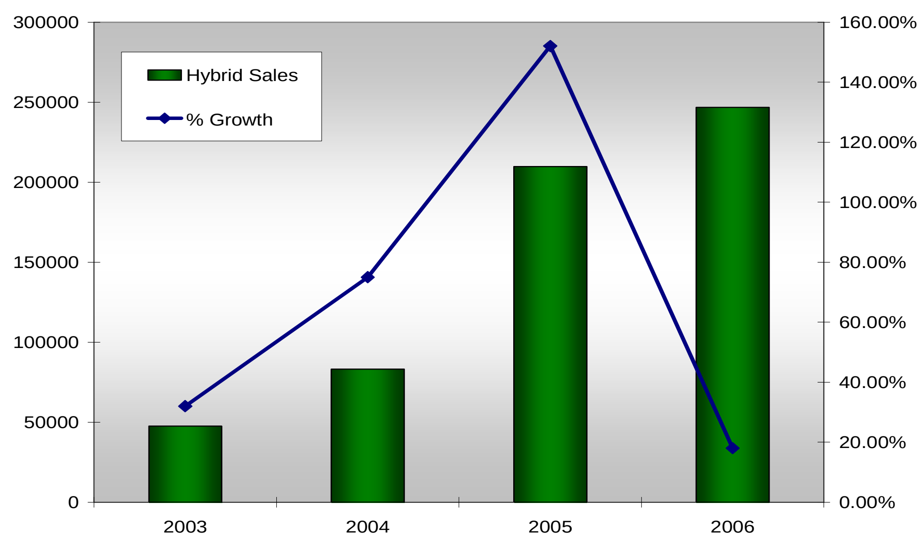
Current Treatment in the Regulation: AT PZEVs earn a range of credits depending on the characteristics of the vehicle that make it ZEV enabling. Examples include electric drive components, batteries, compressed gas fuel tanks, and all electric range. Table 6.2, below, illustrates the variety of vehicle types and credits that may be earned by AT PZEVs.

Table 6.2
Example AT PZEV Credits Per Vehicle

Vehicle Type	Total Credit Per Vehicle		
	2009-2011	2012-2014	2015+
Type C Hybrid (Mild)	0.4	0.2	0.2
Type D Hybrid (Moderate, e.g. Honda Civic)	0.6	0.55	0.45
Type E Hybrid (Strong, e.g. Toyota Prius)	0.7	0.65	0.55
Compressed Natural Gas Vehicle	0.7	0.7	0.7
PHEV with 20 Miles All Electric Range	4.0	2.1	2.1
PHEV with 60 Miles All Electric Range	4.0	2.7	2.7
Hydrogen Internal Combustion Engine Vehicle	4.0	2.2	2.2

Panel Findings: The Panel concluded that AT PZEVs, hybrid electric vehicles in particular, are providing major support to future mass market ZEVs by stimulating advances in electric drive systems, electric accessories, and battery technologies. Additionally, the growing public awareness of electric drive technology was identified as a benefit. The Panel provided the data for Figure 6.5 showing the growth in national sales of hybrid electric vehicles. Rapid growth in sales occurred in initial years, likely fueled by various incentives and rising gasoline prices. The Panel linked continued market penetration to both meeting improved cost targets and market factors such as gasoline prices and available incentives.

Figure 6.5
National Annual Hybrid Sales



Staff findings and recommendations: Hybrid sales in 2007 are increasing dramatically as gasoline prices have again topped $3 per gallon, with projections for continued high prices. With this trend in sales and with the projection for gasoline prices, staff expects sales of hybrid AT PZEVs to remain healthy. Staff expects manufacturers to begin using a variety of AT PZEV types (like PHEVs) which provides flexibility in meeting the requirements. Therefore, staff does not recommend any changes to the AT PZEV portion of the regulation.

6.5 Hydrogen Internal Combustion Vehicles

Issue: The topic of how hydrogen internal combustion engine vehicles (H2ICEs) are valued in the ZEV regulation was raised in the 2003 amendments. The Board was asked to consider allowing H2ICEs to be used in the gold category as they appeared to have a chance for near-term commercial viability, had demonstrated extremely low emission levels, and would help expand the hydrogen refueling infrastructure. The Board decided at the time that H2ICEs were not truly zero emission vehicles. Instead the Board directed staff to create sufficient regulatory incentive outside of the gold category to encourage introduction of H2ICEs. One major manufacturer still considers this technology as zero emitting and since 2003, has added exhaust after treatment to make its H2ICE vehicle virtually emission free. Staff asked the Panel to explore this technology further.

Current Treatment in the Regulation: H2ICEs earn a silver credit of 13.8 through 2008. H2ICEs produced between 2009 and 2011 earn 6.9 credits per vehicle and 2.2 credits per vehicle in 2012 and beyond (see Table 6.2). They are not considered “pure” zero emission vehicles within the regulation because they emit small amounts of oxides of nitrogen.

Panel Findings: The Expert Panel’s opinion is that H2ICEs could provide minor benefits to future mass market ZEVs (for fuel cell vehicles), limited to advancing onboard vehicle hydrogen storage and hydrogen infrastructure. Further, they caution that if the relative incentives change, it could cause a shift in resources away from fuel cell vehicle development to fund H2ICEs. Currently, H2ICE technology is being pursued by only two manufacturers.

Staff findings and recommendations: While at least one manufacturer recognizes technical promise for H2ICEs, the question remains; should H2ICEs count toward meeting the pure ZEV requirements? Staff recommends against allowing H2ICEs to be used in the gold category. This recommendation is based on the original concern that H2ICEs are not zero emission. Even with sophisticated after treatment manufacturers cannot guarantee that H2ICE vehicles will stay emission free throughout their useful lives. For this reason, staff does not recommend opening up the pure ZEV category as an incentive to bring H2ICEs to market.

Staff believes, however, that there is sufficient credit for H2ICEs in the silver category should a manufacturer decide to produce H2ICEs for AT PZEV credit.

6.6 Neighborhood Electric Vehicles

Issue: Prior to 2003, neighborhood electric vehicles could be used to meet ZEV obligations, earning relatively high credit levels with fairly low cost. A few manufacturers took advantage of this compliance path and delivered a large number of NEVs to California. The resulting glut of credits created a challenge for implementation of the ZEV regulation and the Board reacted in 2001 by drastically reducing the credits earned per vehicle and limiting the amount of banked NEV credits that could be applied towards compliance in a given year. The question has been raised to the Board since then, did we overreact? NEVs are after all zero emission vehicles, displacing daily driving and avoiding emissions from cold starts. Staff committed to return to the Board with an assessment of the air quality benefits of NEVs based on data from real world operation, and a reassessment of the appropriate credit levels.

Current Treatment in the Regulation: The credit earned by NEVs is outlined below:

Table 6.3
NEV Credits

2003	2004-2005	2006 +
1.25	0.625	0.15

Panel Findings: The Panel found that NEVs do not contribute to the advancement of technology used in full performance ZEVs. The batteries, drive systems, brakes, etc. are not compatible with full size vehicles. However, they agreed that NEVs are helpful in solving emissions, greenhouse gas and energy independence issues and they are commercially viable.

Staff findings and recommendations: Staff has been presented with extensive data tracking the daily use of NEVs, demonstrating the emissions benefit of NEVs. User surveys indicated NEVs were used for two out of every three trips and the length of trips was sufficient to offset the emissions of a cold start of a conventional vehicle. Given the air quality data benefits presented, it would appear appropriate to consider an increased credit value for NEVs. The staff recommends the Board direct staff to adjust the credit value appropriately to reflect the value of NEVs for emission reduction.

7.0 Additional Issues

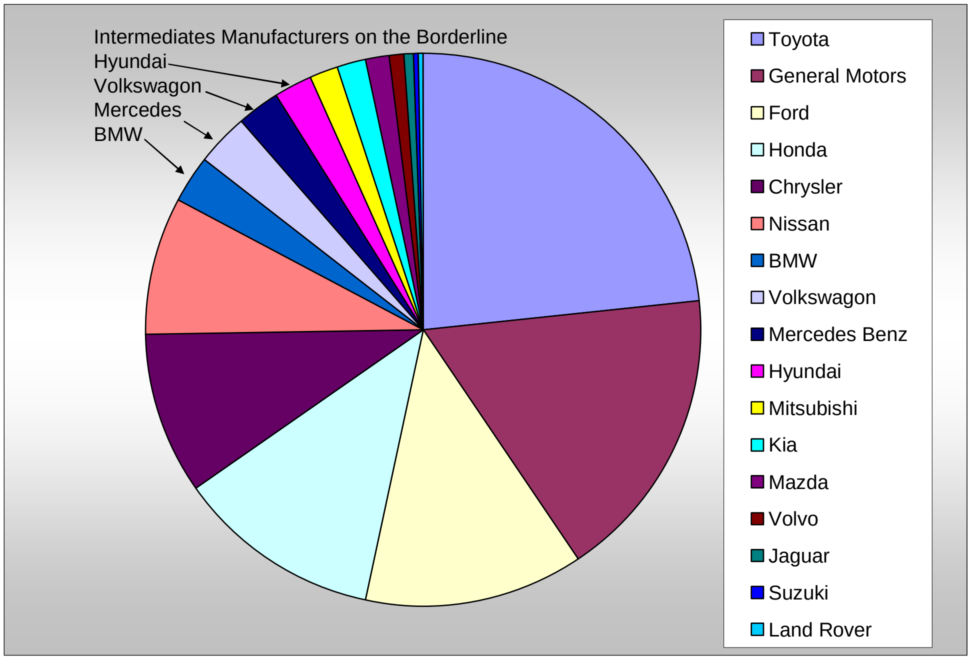
As implementation of the ZEV regulation proceeds staff has identified several issues that the Board should be aware of and that may need adjustment. These include the definition of intermediate volume manufacturers, the “travel” provisions allowing fuel cell vehicles placed in any state that has adopted the ZEV regulations to count towards compliance in California, and regulatory incentives for even cleaner conventional vehicles.

7.1 Intermediate Volume Manufacturers

The ZEV regulation defines an intermediate manufacturer as a company having annual California sales between 3,001 and 60,000 vehicles. The Board established this definition so that smaller manufacturers would not have to invest in development of pure ZEVs. At the time this definition was created, the break between intermediate and large was established at 60,000 vehicles because there was clear distinction in the market place between companies above that threshold and those below.

At this time there are several manufacturers that are approaching or have passed the 60,000 vehicles per year threshold and will become subject to the full ZEV obligation after a period of time established in the regulation (six-year lead time). These are companies that are now complying with the ZEV program using a higher percentage of PZEVs. However, as illustrated in Figure 7.1, below, a significant gap still exists in the market place between large manufacturers and the next group of manufacturers traditionally thought of as intermediate.

Figure 7.1
Market Share of Manufacturers in California
Average production 2003 - 2005



For this reason, staff intends to examine the implications of adjusting the intermediate volume manufacturer definition. This examination is not trivial. There are issues surrounding product development, compliance strategies and impacts to large manufacturer obligations in coming phases that would be affected by a change to the definition.

7.2 Section 177 State "Travel Provisions"

In 2003, the manufacturers expressed concern about the multiplicative effects of California's ZEV regulations across the country as other states adopted and implemented the State's ZEV regulations as allowed by section 177 of the federal Clean Air Act amendments of 1990. These states, referred to as Section 177 states, would cause the ZEV requirement to effectively double. While the Board was determining if the Alternative Path volumes for fuel cells were reasonable and appropriate, the manufacturers were calculating what the requirements would mean for them nationwide, and expressed concerned that these volumes were not necessary to support ZEV technology development and would be unreasonably costly.

The compromise, based on the notion that early demonstrations are best accomplished with small numbers of vehicles, was to allow fuel cell vehicles placed in California (or in other Section 177 states) to count towards compliance in all states (referred to as the travel provision). While the Board was concerned that this might mean that California would loose fuel cell vehicle volume, there was some confidence that California would attract the majority of vehicles because of the California Fuel Cell Partnership effort, developing infrastructure and existing program momentum. Since implementation began, more than 90 percent of all fuel cell vehicles placed to meet the ZEV requirements have been placed in California. Clearly the “leakage” of fuel cell vehicle demonstrations has not been wide-spread. This travel provision no longer applies after model year 2011 vehicles.

While the travel provision is working well in the current phase, issues have been raised about implementation of the provision in later phases, especially with regard to how the vehicle obligations are calculated for states other than California. The travel provision will be an area of the regulation that will need to be reexamined as other parts of the regulation are adjusted.

7.3 Extremely Clean Vehicles

Staff has had recent discussions with industry regarding treatment of conventional vehicles with direct emissions substantially lower than PZEVs. While staff does not believe that vehicles with direct emissions, however low, should receive pure ZEV credit, further investigation is needed to determine how best to encourage the commercialization of such vehicles.

8.0 Summary and Conclusions

The Independent Expert Panel’s review of technologies used to comply with the ZEV regulation has provided a variety of useful measuring sticks by which to determine if the ZEV regulation is on track for the successful mass commercialization of zero emission vehicles. It is clear that progress has been made in many areas and that much work remains before the goal will be met. It is also apparent that there is no single winner among the technologies: many hold promise; all have challenges and benefits. For these reasons, staff concludes the ZEV program is still a critical part of the Air Resources Board’s efforts to attain health based air quality standards and contributes towards meeting the State’s policies on climate change and fuel diversity. Although it is apparent that some changes are needed to the regulation, on the whole, it remains effective and useful.