READY TO ROLL

AN ASSESSMENT OF MASSACHUSETTS' PREPAREDNESS FOR THE ZERO-EMISSION VEHICLE PROGRAM

MASSPIRG
EDUCATION FUND

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MASSPIRG Education Fund

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EXECUTIVE SUMMARY

In the early 1990s, the Commonwealth of Massachusetts took a critical step toward cleaner air by adopting California's Zero-Emission Vehicle (ZEV) program. The program requires automakers to sell specific percentages of zero-emission and near-zero-emission cars. Originally scheduled to take effect in 1998, the start of the program has been delayed twice, first to 2003, then to 2005.

Massachusetts is ready for successful implementation of the ZEV program without further delay. Automotive technology is ready, there is a market for clean cars, and the alternative fuel infrastructure can be put in place quickly. Implementation of the ZEV program will provide both short- and long-term benefits to the state, and would come at only limited cost to automakers and consumers.

Specifically, we find that:

The ZEV program will bring environmental, energy and economic benefits to Massachusetts.

- The ZEV program will help automakers attain the aggressive vehicle emissions reductions envisioned by the Low-Emission Vehicle II (LEV II) program. LEV II is projected to reduce motor vehicle emissions of smog-forming nitrogen oxides by 19 percent by 2020, while producing similar reductions in emissions of air toxics and carbon monoxide.

- Technologies encouraged by the ZEV program – such as hybrid-electric and battery-electric vehicles – can also reduce Massachusetts' emissions of global warming gases. Hybrid-electric vehicles are responsible for approximately 47 percent less carbon dioxide per mile than conventional vehicles, while battery-electric vehicles are responsible for about 43 percent less.

- The ZEV program can enhance Massachusetts' economy by reducing its susceptibility to oil price shocks, encouraging the development of clean vehicle industries within the state, and helping to promote advanced technologies with applications in other sectors of the economy.

The technology exists for automakers to meet the ZEV requirement.

- Nearly a half-million vehicles that run on alternative fuels are currently on America's roads. Automakers have already manufactured thousands of electric vehicles that qualify for the ZEV program, and are beginning to make cars that qualify for partial ZEV credit.

- All six of the major automakers (General Motors, Ford, DaimlerChrysler, Honda, Toyota and Nissan) are projected to produce vehicles that satisfy aspects of the ZEV program by 2005.

- The anticipated cost of the ZEV program to automakers from 2004 to 2006 represents less than one percent of automakers' annual media spending and net profits. Offsetting economic benefits of the program and consumers' willingness to pay more for some ZEV-compliant vehicles will reduce those costs further.

Consumers are eager to buy cleaner cars and have embraced ZEVs wherever they have been introduced.

- Electric vehicle drivers in California and in public-sector fleets express strong satisfaction with their vehicles. Surveys indicate that the majority of EV drivers would recommend the vehicles to others and that EVs fit better within drivers' "real world" driving patterns than owners had anticipated.

- Vehicle fleets in Massachusetts are likely to provide a substantial market for clean vehicles. The state requires 75 percent of its fleet purchases to be alternative-fuel vehicles and 10 percent to be zero-emission vehicles. Clean vehicles have also been shown to fit well within many private fleet applications.

- Demand for battery-electric and hybrid-electric vehicles has outstripped supply. Massachusetts consumers have weathered long waiting lists to purchase the first generation of hybrid-electric vehicles and automakers are preparing to increase production to meet the demand.

- The ZEV program is unlikely to have a substantial negative effect on overall new vehicle prices or the price of most ZEV-compliant vehicles. Automakers may even choose to assume the costs of more expensive "pure ZEVs" in the short run in order to maximize long-run profits and build market share.

Massachusetts can have the infrastructure in place to support the ZEV program by 2005.

- The vast majority of vehicles covered by the ZEV program – such as clean conventional cars and hybrid-electric vehicles – run on gasoline and will require no special infrastructure.

- While Massachusetts currently lacks extensive infrastructure for alternative fuel vehicles, fueling and recharging stations can be erected quickly and with limited cost. California and New York State provide workable models of how this can be done.

Maintaining a strong ZEV requirement in Massachusetts is both attainable and beneficial to the state. To ensure successful implementation of the program, the state should take a leadership role in coordinating the expansion of alternative-fuel infrastructure and educating the public about clean cars, and work to secure both public and private resources to support those efforts.

INTRODUCTION

In the early 1990s, the Commonwealth of Massachusetts took an important step toward reducing air emissions from motor vehicles when it adopted the California Low-Emission Vehicle (LEV) program and Zero-Emission Vehicle (ZEV) requirement. Despite intense pressure from automakers, Massachusetts has retained its commitment over the past decade to enforcing the strongest possible emission standards for automobiles and to bringing about a transition to even cleaner vehicles in the future.

The need for such a transition has grown more urgent over the past decade. The number of miles traveled on Massachusetts roads increased by about 13 percent between 1991 and 2000, muting the effects of more stringent air pollution standards for automobiles.[1] During the summer of 2001, Massachusetts registered 27 days on which levels of ozone smog exceeded healthy levels, the most since 1988.[2] Volatility in gasoline markets has led to periodic price spikes that underscore the need to diversify the state's transportation fuel mix.

At the same time, rapid advances in technology have brought cleaner vehicles closer to reality. Electric vehicles have been transformed from car-show concepts to daily reality for thousands of drivers. A new class of vehicles – hybrid-electrics – has made its way to automobile dealerships, and proven extremely popular. Other alternative-fuel vehicles – such as those that run on compressed natural gas – have continued to make their way into vehicle fleets in Massachusetts and elsewhere. Technological improvements have made it possible to build conventional vehicles that approach zero emissions. And great strides have been made in the development of fuel cells, which many believe are the clean automotive technology of the not-too-distant future.

Changes made to the ZEV program over time have made its goals more readily attainable for automakers. Interim requirements for the phase-in of electric vehicles during the 1998-2003 timeframe were eliminated. Incentives were devised to promote the adoption of hybrid-electric, natural gas, and other clean vehicles within the program. Additional credits were made available to automakers for early adoption of ZEV-compliant vehicles, improved fuel efficiency, fast-recharging of electric vehicles and a host of other technological advances.

The conditions are right for Massachusetts to finally make good on its commitment to the ZEV program. This report demonstrates that consumers, automakers, and the state's alternative fuel infrastructure are, or could soon be, ready for the roll-out of the ZEV program. It also demonstrates that the ZEV program will lead to cleaner air, enhance the state's long-term energy security, and provide important economic benefits.

Additional changes to the ZEV program proposed by Massachusetts and other northeastern states would make the ZEV requirement even easier for automakers to achieve. While the northeastern states' alternative compliance plan (ACP) runs the risk of further delaying the introduction of "pure ZEVs," it gives automakers additional flexibility to meet the ZEV requirement by providing more ultra-clean conventional vehicles in the early years of the program.

Automakers have long been aware of Massachusetts' strong commitment to the development of cleaner cars. Many, if not all, of those automakers now stand ready to fulfill that commitment. A decade after the program's adoption, Massachusetts is ready for ZEVs.

The Zero-Emission Vehicle Program in Massachusetts

History

The ZEV program in Massachusetts has its roots in a quirk in environmental regulation in the United States, one whose history goes back to the mid-1960s.

California has long experienced severe air pollution problems, owing partially to its automobile-centered culture and its smog-conducive climate. In the early 1960s, the state began taking action against pollution from automobiles, pioneering new strategies for reducing tailpipe emissions.

At the same time, the federal government was beginning to awaken to the dangers posed by automobile air pollution. In 1970, Congress made its first comprehensive attempt to deal with air pollution by passing the Clean Air Act. One provision of the law barred individual states from regulating automobile emissions – a move intended to protect automakers from having to manufacture 50 separate cars for 50 states. However, it preserved a special place for California, allowing the state to adopt tougher emission standards to address its unique air pollution problems.

By 1977, with more cities facing smog problems similar to those in California, Congress gave the states – through Section 177 of the Clean Air Act – the opportunity to adopt California's vehicle emission standards rather than sticking with the weaker national standards. Massachusetts took advantage of that opportunity by adopting California auto emission standards in the early 1990s. California's 1990 revisions to its emission standards, which included the ZEV requirement, went into effect in Massachusetts upon approval by EPA in 1993.

The original ZEV program required that two percent of automobiles sold beginning in 1998 be zero-emission vehicles, with the percentage increasing to five percent in 2001 and 10 percent in 2003. In 1996, however, the California Air Resources Board (CARB) – the body empowered to set auto emission standards in California – dropped all ZEV requirements from 1998 to 2003 in exchange for a commitment from major automakers to produce between 1,250 and 3,750 advanced battery-electric vehicles for sale in California between 1998 and 2000.[3]

California's separate deal with the automakers essentially undercut the northeastern states that had adopted the ZEV requirement. Massachusetts attempted to enforce the terms of California's memorandum of agreement (MOA) with the automakers, but was rebuffed in federal court.[4] The result of the court's decision was that Massachusetts was left with no enforceable zero-emission vehicle program until 2003.

In the meantime, however, CARB continued to modify California's ZEV program. In 1998, the program was amended to allow manufacturers to receive partial ZEV (PZEV) credit for near-zero-emission vehicles. In 2001, CARB again amended the program to encourage the development of advanced technology vehicles and allow manufacturers to claim additional credits toward compliance with the program. Those regulatory changes are being finalized as this report goes to press. Because other states adopting California's air pollution standards must give automakers two model years of lead time before implementation, this effectively pushed back the introduction of the Massachusetts ZEV requirement to the 2005 model year.

On December 31, 2001, the Massachusetts Department of Environmental Protection (DEP) filed an emergency regulation implementing the latest changes to the California ZEV program – a move that was necessary to ensure that the changes would go into effect in 2005.[5] At the same time, DEP proposed an alternative compliance plan (ACP) to give automakers another option for complying with the program. The details of the ACP will be examined later in this section.

How It Works

The percentages of ZEV and near-ZEV vehicles called for under the ZEV program do not represent actual percentages of cars sold. Rather, automakers have many opportunities to earn credits toward the ZEV requirements that reduce the actual number of ZEV-compliant vehicles they must produce.

In recent years, California has moved toward policies that reduce the number of pure ZEVs required of automakers, while increasing the number of extremely clean vehicles eligible for partial ZEV (or PZEV) credits.

The key elements of the program are as follows:

- **Pure ZEVs** – The latest version of the California ZEV program requires that two percent of the cars sold by large volume manufacturers by 2003 be "pure ZEVs"; those with no tailpipe or fuel-related evaporative emissions. Currently, that means battery-electric vehicles (EVs), but it is expected that this standard will soon lead to commercial introduction of hydrogen fuel cells. In early years of the program, manufacturers can meet the requirement either with full function ZEVs, or with "city" or "neighborhood" electric vehicles that have a smaller range and travel at lower speeds. Credits for neighborhood electric vehicles are scheduled to decrease over time, so that by 2006 they will count for only 0.15 of a full-function ZEV.[6]

- **Advanced technology PZEVs (AT-PZEVs)** – Manufacturers will be allowed to satisfy up to two percent of the 10 percent ZEV requirement by marketing AT-PZEVs powered by compressed natural gas, hybrid-electric motors, methanol fuel cells, or other very clean means. Such vehicles must meet LEV II's strict super-low-emission vehicle (SULEV) emission standards, have "zero" evaporative emissions, and have their emissions control systems certified and under warranty for 150,000 miles.[7] Current hybrid-electric vehicles such as the Toyota Prius do not yet meet those standards, but there is no technological reason they cannot. If manufacturers fail to fulfill the two percent allocated to AT-PZEVs, they must sell pure ZEVs instead.

- **Partial ZEV (PZEV) credits** – The law also allows manufacturers to meet up to 6 percent of the 10 percent ZEV requirement by marketing conventional, gasoline-powered cars that meet the same criteria as AT-PZEVs. Under the 2001 rules, their introduction will be phased in between 2003 and 2006. Intermediate volume manufacturers – those that sell fewer than 60,000 light- and medium-duty vehicles in California annually – may meet the entire ZEV percentage requirement with PZEV credits.

- **Other credits** – Automakers can also receive additional credits for early introduction of ZEVs or for including technologies that enhance vehicle performance, such as fast recharging, extended range, and extended warranties on batteries or fuel cells.

- **Scope** – In the initial years of the program, the ZEV requirement applies only to passenger cars and light trucks. Beginning in 2007, heavier sport utility vehicles, pickup trucks and vans will be phased into the sales figures used to calculate the ZEV requirement

TABLE 1: ZEV PERCENTAGE REQUIREMENT[8]

Model Years	Minimum ZEV Requirement
2003-2008	10 percent
2009-2011	11 percent
2012-2014	12 percent
2015-2017	14 percent
2018-	16 percent

Another important change adopted by CARB in 2001 is a gradual ratcheting up of the ZEV requirement from 10 percent to 16 percent over the next two decades, as shown in Table 1. However, the ample opportunities for additional credits and multipliers available to manufacturers will significantly reduce the amount of vehicles that must be sold – particularly in the early years of the program. The complexity of the ZEV program credit scheme makes it impossible to predict how many of each type of ZEV or PZEV vehicle will be on the road, but the state of

Massachusetts has estimated the number of ZEV, AT-PZEV and PZEV vehicles that would be sold in the state between 2005 and 2012 based on the California credit scheme. (See Table 2)

TABLE 2: ESTIMATED SALES IN MASSACHUSETTS UNDER CALIFORNIA ZEV PROGRAM

Model year	ZEV	AT-PZEV	PZEV
2005	900	4,430	60,542
2006	1,215	6,582	96,571
2007	1,332	7,128	102,899
2008	1,383	8,746	109,227
2009	1,907	11,711	115,555
2010	2,121	12,488	121,883
2011	2,254	13,266	128,211
2012	3,137	16,742	133,794
Total Sales	**14,249**	**81,093**	**868,682**

THE NORTHEASTERN ALTERNATIVE COMPLIANCE PLAN

The three northeastern states that had previously adopted the ZEV program (Massachusetts, New York and Vermont) worked with CARB, auto manufacturers and others to devise an alternative implementation schedule that automakers could follow to comply with the ZEV program. The alternative compliance plan (ACP) is proposed to be written into the regulations of each of the three states to avoid the legal pitfalls that followed California's extra-regulatory memorandum of agreement with the automakers.

While the ACP is based on the California ZEV requirement, it differs in several key respects:

- **Early implementation**: To qualify for the ACP, automakers must begin to fulfill the ZEV requirement beginning in the 2004 model year; a year earlier than under the standard ZEV program.

- **Reduced pure ZEV requirements**: Automakers may comply with the ZEV percentage requirement in 2004 by using only PZEV credits. No pure ZEVs would be required by the program until 2006 model year, with the program's requirements becoming identical with the California program in 2007.

- **Phase-in multipliers**: Automakers taking part in the ACP are eligible for multiple credits for any ZEVs and PZEVs they sell prior to 2007 model year. ZEVs sold between 2002 and 2004 receive a multiplier of 3, while PZEVs receive a multiplier of 1.5. Multipliers are gradually reduced for the 2005-2006 model years and are eliminated in 2007.

- **Infrastructure and transportation system credits**: Manufacturers can satisfy up to a quarter of the 10 percent ZEV requirement through special projects to promote the development of alternative fuel refueling infrastructure, encourage the use of fuel cells and personal electric vehicles, and place advanced technology vehicles in "innovative transportation systems." These credits end in 2007.[9]

The Massachusetts DEP estimates that the ACP would result in the number of ZEV, PZEV and AT-PZEV vehicle sales over the 2004-2007 period shown in Table 3 (next page), not counting the use of infrastructure and transportation system credits.

A graphic representation of the difference between the two plans is presented in Figures 1 and 2 (next page). As the graphs show, automakers are permitted to manufacture significantly fewer ZEVs and AT-PZEVs in the 2005-2006 period, in exchange for an initial boost in the number of PZEVs offered for sale in 2004. However, even the number of PZEVs required under the plan will be lower for part of the phase-in period than would be the case under the California ZEV rules. Again, these figures do not include credits for infrastructure and transportation system programs – which can offset up to 25 percent of the ZEV requirement until 2007. The ACP, therefore, offers automakers that choose to participate the option to significantly reduce the number of clean cars they must manufacture and sell prior to 2007.

TABLE 3: ESTIMATED SALES IN MASS. UNDER NORTHEAST ALTERNATIVE COMPLIANCE PLAN

Model year	ZEV	AT-PZEV	PZEV
2004	-	-	30,316
2005	-	2,215	61,493
2006	405	4,388	76,908
2007	1,332	7,182	102,899

While the ACP offers a direct benefit to automakers, several automakers – including General Motors and DaimlerChrysler – have challenged New York State's inclusion of the ACP in federal court, arguing that it is not "identical" with California regulations. This report, therefore, will focus on the ZEV rules as they currently stand in California.

Why ZEVs?

The ZEV program holds several important benefits for Massachusetts. It provides environmental benefits by helping the state reach its air pollution reduction goals and reduce emissions of greenhouse gases. It provides energy conservation benefits by promoting the use of more energy-efficient vehicles. And it could provide economic benefits by enhancing the state's energy security and encouraging the development of high-tech alternative vehicle industries within the state.

AIR QUALITY BENEFITS

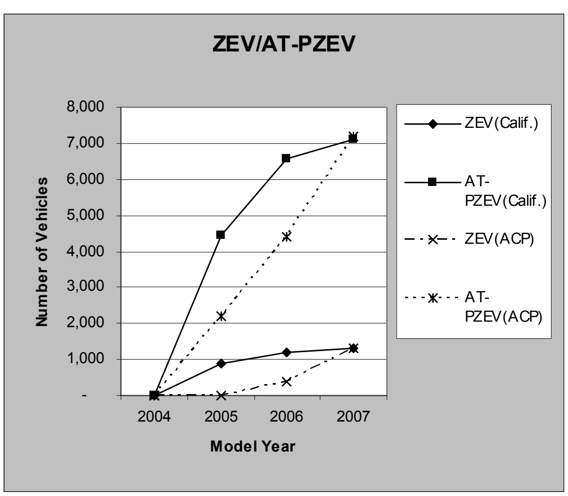
The ZEV program will have both short- and long-term air quality benefits for Massachusetts.

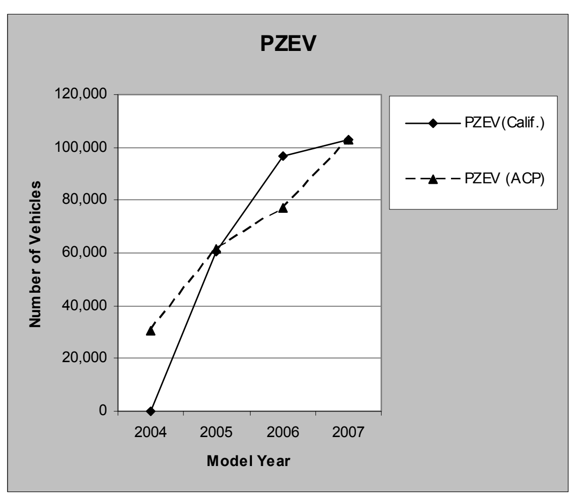
In the short term, the ZEV program is an integral part of the Low-Emission Vehicle II (LEV II) standards adopted by Massachusetts in 1999 and scheduled to go into effect in 2004. The LEV II standards, like the ZEV program, are based on California regulations and are significantly tougher than the comparable federal standards, known as Tier 2.

The Massachusetts Department of Environmental Protection has projected that LEV II (together with adoption of LEV I standards for medium-duty vehicles in the pre-2004 period) will lead to significant reductions in emissions of a host of pollutants from motor vehicles. Specifically, DEP projects that LEV II will lead to:

- A 20 percent reduction in non-methane hydrocarbon emissions – which include many smog-forming volatile organic compounds – from motor vehicles versus federal Tier 2 standards.
- A 19 percent reduction in motor vehicle emissions of smog-forming nitrogen oxides versus Tier 2.
- A 17 percent reduction in carbon monoxide emissions from motor vehicles.

FIGS. 1, 2 : CALIFORNIA ZEV REQUIREMENT VS. NORTHEAST ACP





- Reductions of 24 percent, 26 percent and 23 percent, respectively, in motor vehicle emissions of benzene, 1,3-butadiene and formaldehyde – all of which are known or probable human carcinogens.[10]

Under the LEV II program, manufacturers may certify their light-duty vehicles to one of a series of emissions "bins." Each bin includes limits on the emissions of a set of pollutants, with some bins allowing more pollution and others less. Manufacturers may certify vehicles to whichever bin they choose, so long as the average non-methane organic gas (NMOG) emissions of their entire fleet fall below a particular level. The fleet average NMOG requirement declines over time, forcing manufacturers to certify increasing numbers of vehicles to cleaner bins.

In addition, LEV II requires automakers to meet more stringent standards for evaporative emissions of hydrocarbons – those emissions that emanate from parts of the vehicle other than the tailpipe. LEV II standards represent a nearly 80 percent reduction in evaporative emissions from previous standards, while federal Tier 2 standards represent only a 50 percent reduction.[11]

The ZEV requirement plays an integral role in helping automakers meet the LEV II standards, and yields emission reductions above and beyond those in the program.

- By requiring automakers to certify specific numbers of vehicles to the two cleanest bins – ZEV and SULEV – the ZEV program frees up automakers to make and sell more vehicles in the "dirtier" bins of the program.

- Requirements that PZEVs have their emissions systems certified for a useful life of 150,000 miles (as opposed to the 120,000-mile useful life of LEV II) and that manufacturers place those systems under warranty for their full useful lives should reduce the degradation of emissions systems, ensuring that vehicles comply with emission standards for longer periods of time.

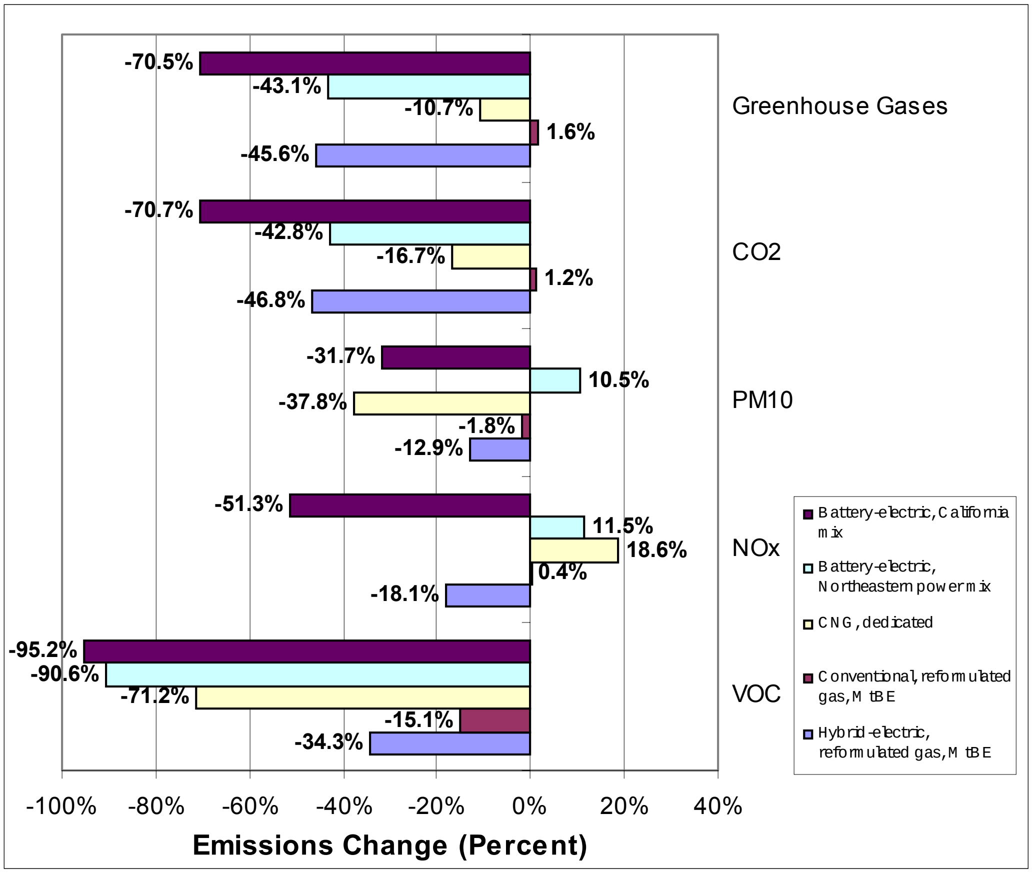
- The zero evaporative emission requirement for PZEVs will lead to further reductions in evaporative hydrocarbon emissions beyond the levels established by LEV II.

In its 2000 review of the California ZEV program, CARB estimated that vehicles manufactured between 2003 and 2010 would release approximately 7 percent less combined reactive organic gases and nitrogen oxides in the South Coast region of California under a 4% ZEV/6% PZEV configuration of the ZEV program than if there were no ZEV requirement in place.[12] Massachusetts can expect to see similar reductions.

In the longer term, the ZEV requirement will encourage the development of technologies that can yield significant reductions in emissions of air pollutants – including emissions of greenhouse gases responsible for global warming.

Zero-emission vehicles will obviously release fewer pollutants from their tailpipes than conventional vehicles. (EVs, for example, have no tailpipes.) To fully understand the impact of the ZEV requirement one must look at emissions from the entire fuel cycle, from fuel extraction and refining through emissions from vehicles and power plants that generate electricity to power vehicles.

FIG. 3: CHANGE IN PER-MILE EMISSIONS OF CLEANER PASSENGER CARS VERSUS CONVENTIONAL GASOLINE INTERNAL COMBUSTION CARS[13]



CO_2: Carbon dioxide
PM_{10}: Particulate matter less than 10 microns in diameter
NOx: Nitrogen oxides
VOC: Volatile organic compounds

Such a fuel-cycle analysis shows that near-term alternative technologies such as hybrid-electric vehicles, compressed natural gas (CNG) vehicles, and electric vehicles release significantly less carbon dioxide and greenhouse gases than internal-combustion vehicles burning conventional gasoline. (See Figure 3) Hybrid-electrics hold clear advantages in all pollutant categories, while CNG vehicles are generally cleaner, but may release more smog-forming nitrogen oxides.[14]

With regard to electric vehicles, much depends on what sources are used to generate the electricity. In the northeast, where a significant amount of power comes from older coal- and oil-fired power plants, EVs may lead to increased releases of nitrogen oxides, sulfur oxides and particulate matter. This is not true in California, which uses cleaner sources for its electricity. Eventual shifts in power production in the northeast to renewable energy sources such as solar and wind, or to cleaner natural gas, would give EVs a distinct pollution advantage over conventional vehicles.

Shifting to alternative vehicles such as hybrids and EVs will lead to significant reductions in per-mile emissions of many pollutants and will reduce the contribution of Massachusetts cars and light trucks to global warming. To the extent that the ZEV requirement hastens widespread adoption of these technologies, development of improved technologies, and displacement of travel in conventional gasoline vehicles, it will have a profound and lasting effect on air quality in the Bay State.

ENERGY BENEFITS

Another benefit of the ZEV program is that it reduces Massachusetts' dependence on oil as a transportation fuel, enhancing the state's long-term energy security and reducing the need to import foreign oil or drill in ecologically sensitive areas.

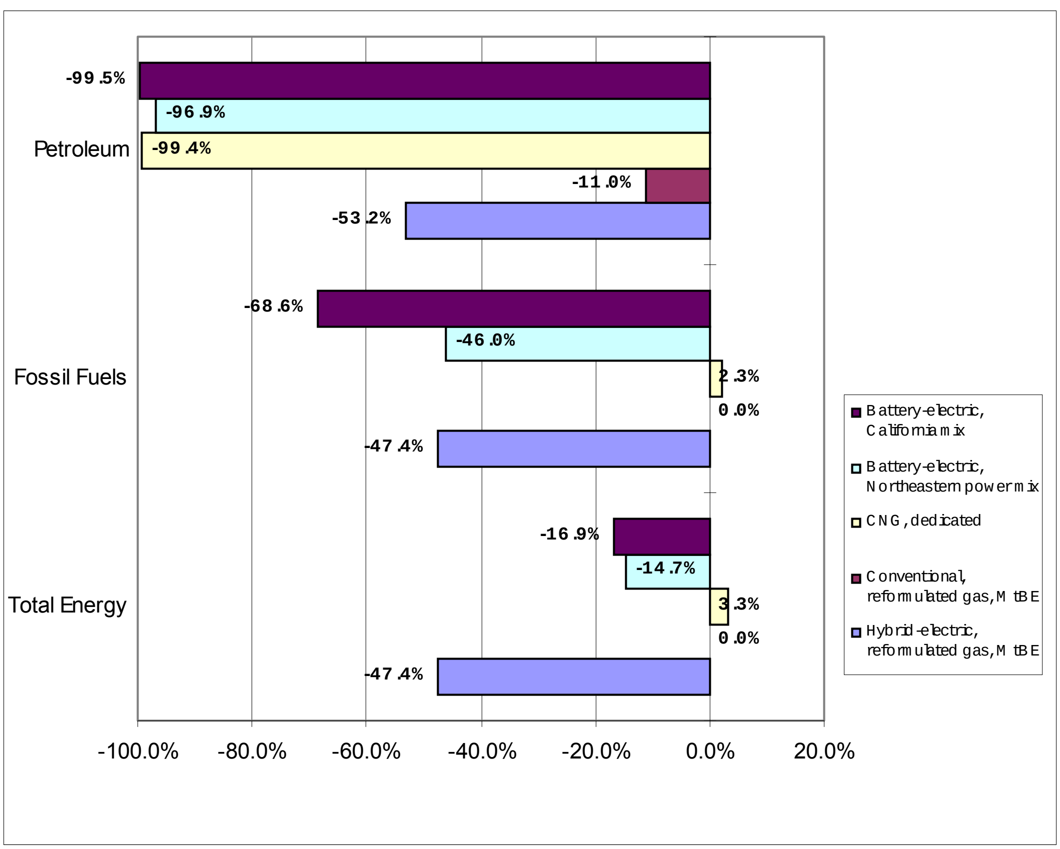
Many near-term alternative vehicle technologies have the benefit, along with lower emissions, of being more energy efficient than conventional vehicles. As Figure 4 demonstrates, hybrid-electric and electric vehicles are significantly more energy-efficient on a fuel-cycle basis than today's conventional vehicles.[16] On a per-mile basis, hybrids consume slightly more than half as much energy as conventional vehicles, while electric vehicles use between 15 and 17 percent less energy. Again, as is the case with emissions, more energy-efficient methods of electric generation will lead to greater gains in efficiency for electric vehicles.

ECONOMIC BENEFITS

As will be discussed in more detail below, the ZEV requirement will impose some additional new costs on automakers. However, the ZEV program also holds the promise of economic benefits for the state.

First, numerous Massachusetts businesses are already engaged in clean vehicle development. Woburn-based Solectria Corporation, for example, has been engaged in the business of building electric vehicles and components since

FIG. 4: CHANGE IN PER-MILE ENERGY USE FOR CLEANER PASSENGER CARS VERSUS GASOLINE INTERNAL COMBUSTION VEHICLES[15]



1989. The company recently announced a shift in focus to the development of components for electric and hybrid-electric vehicles, and for distributed electric generation systems.[17] Other local businesses are involved in the development of fuel cell technologies. Establishment of a steady market for ZEVs in Massachusetts could attract other such businesses to the state, creating high-tech jobs.

Second, the technological improvements brought about by the ZEV requirement will have applications well beyond vehicles. Fuel cells could have an application in distributed generation of electricity, providing individuals and businesses with a cushion against a California-style failure of centralized power generation and transmission markets without the pollution and public health risks posed by diesel generators. Advances in battery technology and electric drive systems sparked by the ZEV requirement have already found other applications both within and outside of the automotive industry.[18] Development of these technologies will benefit the economy both inside Massachusetts and across the country.

In addition, as noted above, the energy efficiency benefits of the ZEV program hold the potential to safeguard the state's economy from future oil price shocks and to save individual consumers and fleets money on motor fuel.

Summary

Maintaining the ZEV program will have multiple benefits for Massachusetts. It will lead to reduced air emissions from the vehicles covered by the program and will help Massachusetts attain the aggressive emission reduction goals of LEV II. It will also likely lead to improved energy efficiency for the vehicles manufactured to comply with the program. But the ZEV program potentially has even more profound benefits – hastening the development and implementation of a host of new energy technologies that have the power to transform society for the better.

Massachusetts is well-suited to meet the goals of the early years of the ZEV program, with or without the ACP. With reasonable effort by all concerned – automakers, state officials and the public – those goals can be readily achieved.

To evaluate Massachusetts' readiness to implement the ZEV requirement, it is necessary to answer three questions:

- Do auto manufacturers have access to the technology needed to meet the requirement?
- Will consumers purchase ZEVs or near-ZEVs if they are made available?
- Can sufficient infrastructure be put in place to support vehicles produced to satisfy the ZEV requirement?

The answer to each of these questions is "yes."

TABLE 4: LIGHT-DUTY ALTERNATIVE FUEL VEHICLES AVAILABLE IN MODEL YEAR 2001[19]

Manufacturer	Model	Fuel	Body
Dodge	Ram van/wagon	CNG	Van
Ford	Crown Victoria	CNG	Sedan
Ford	F-series	CNG	Truck
Ford	Econoline	CNG	Van/wagon
Ford	Ranger	EV	Truck
Ford	E-series cutaway	CNG	Van
GM	EV1	EV	Coupe
Honda	Civic GX	CNG	Sedan
Nissan	Altra	EV	Sedan
Nissan	Hypermini	EV	Mini
Solectria	Force	EV	Sedan
Solectria	Citivan	EV	Van
Solectria	Flash	EV	Truck
Toyota	Camry	CNG	Sedan
Toyota	Rav4	EV	SUV

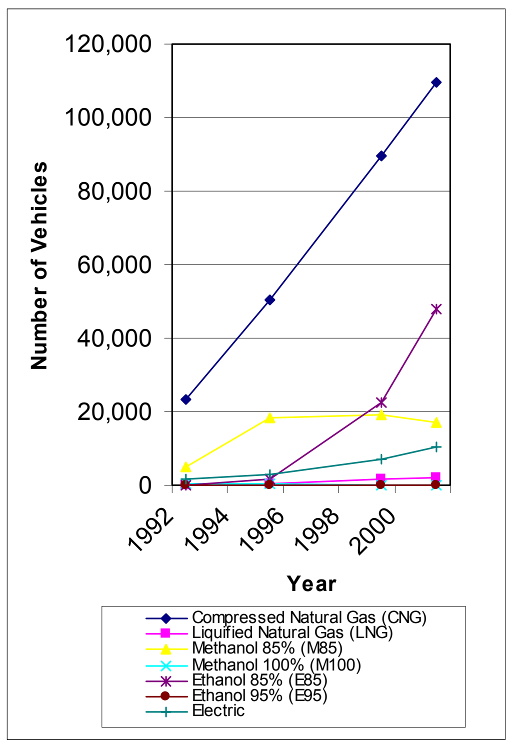
MANUFACTURER READINESS

The technology to make zero-emission and near-zero-emission vehicles is clearly available. Several technologies – including battery-electric, hybrid-electric, natural gas, and clean conventional vehicles – have the potential to fulfill portions of the ZEV requirement in the near term. And the development of new technologies such as fuel-cell vehicles promises to make the increasing ZEV sales percentages in future years of the program attainable for automakers.

Alternative Fuel Cars on the Road

Automakers are already making significant numbers of vehicles that run on fuels other than gasoline. The number of alternative-fuel vehicles on the road has nearly doubled over the last decade – from just over 250,000 in 1992 to more than 450,000 in 2001. Vehicles fueled by liquid (LNG) and compressed (CNG) natural gas, ethanol (E85), and electricity have seen the most dramatic increases. (See Figure 5)[20] Propane (LPG) remains the most common alternative fuel for vehicles, but its use has not increased significantly since the mid-1990s.

FIG. 5: ALTERNATIVE FUEL VEHICLES IN USE IN U.S. (EXCLUDING PROPANE)[21]



Excluding flexible fuel and bi-fuel vehicles (which can either run on gasoline or an alternative fuel), auto manufacturers produced 16 models of light-duty alternative-fuel vehicles in the 2001 model year, as well as a number of alternative-fuel heavy-duty trucks and buses. As can be noted from Table 4, automakers have focused their development of dedicated alternative-fuel vehicles on two technologies: CNG and electric vehicles. While it is possible that ethanol, propane and other vehicles could be manufactured to meet ZEV program standards, it is more likely that they will be met by battery-electric vehicles (currently the only pure ZEVs on the market), CNG vehicles, hybrid-electric vehicles (many of which could qualify for AT-PZEV credit), clean conventional vehicles, and a technology that some believe will be the pure ZEV of the near future: hydrogen fuel cells. This analysis will therefore focus on those vehicles.

Pure ZEVs: Battery Electric Vehicles

Major automakers (a category that includes General Motors, Ford, DaimlerChrysler, Nissan, Honda and Toyota) have already produced battery-electric vehicles in the quantities needed to comply with the early years of the ZEV requirement in Massachusetts. In addition, all the major automakers – with the exception of General Motors and Honda – either are currently producing or have plans to produce electric vehicles that will be eligible for credit as pure ZEVs.

From 1998 to 2000, automakers sold more than 2,300 electric vehicles in California to fulfill the terms of CARB's memorandum of agreement with the automakers.[22] In its 2000 biennial review of the ZEV program, CARB's staff was clear: "There is no technological barrier to building battery powered ZEVs; the issue is cost and consumer acceptance."[23] These issues will be addressed later in this report, but comparison of the California production figures to those anticipated for Massachusetts underscores the attainability of the ZEV requirement in Massachusetts. Should automakers produce for Massachusetts as many vehicles as they did under the California MOA, they would comply with the pure ZEV requirement through the 2006 model year under the current ZEV rules.

Toyota's RAV4-EV (shown above) is the first battery-electric vehicle by a major manufacturer available for retail sale in the United States. The vehicle went on sale in February 2002 in California.
Photo: Electric Vehicle Association of Canada

With the 2000 expiration of the memorandum of agreement, automakers took several different strategies toward future production of battery-electric vehicles. Some, such as General Motors and Honda, discontinued their EV programs. Others, such as Toyota, Nissan and Ford, continued to manufacture EVs for fleet sales. Toyota, in fact, has moved to expand the availability of their existing EV model, making the RAV4-EV – previously available only to fleets – available for individual lease.[24]

One significant recent change is the emphasis of several automakers – Ford and DaimlerChrysler, in particular – on the marketing of "city" and "neighborhood" electric vehicles. City and neighborhood EVs are low-speed, low-range vehicles designed to serve specific travel niche markets. City EVs are appropriate for use as a second car and as "station cars" – vehicles used for transportation to and from a central point, such as a commuter rail station. Ford's Th!nk City EV, for example, has an all-electric range of 50 miles and can travel at a top speed of 62 miles per hour.[25] The vehicle will be available for purchase in California beginning this fall.

Neighborhood electric vehicles travel at slower speeds and have more limited range than City EVs. They may or may not be approved for street travel, although they have applications in settings such as college campuses, housing developments, and other locations where full-function cars might not be appropriate. DaimlerChrysler's GEM neighborhood electric vehicle, for example, has a range of 30 to 35 miles and travels at a top speed of 25 miles per hour. It also has the advantages of low price (about $7,000) and the ability to be recharged through an ordinary household outlet.[26]

"City" electric vehicles – like the Ford Th!nk above – could provide another way for automakers to meet the pure ZEV portion of the ZEV requirement.
Photo: Electric Vehicle Association of Canada

City and neighborhood vehicles may not provide a long-term solution to dependence on gasoline for automotive travel, but they may displace some travel in conventional automobiles, spur further development of battery-electric vehicle technology, and provide another option for automakers to meet the pure ZEV portion of the ZEV requirement – particularly in the early years of the program. Under California ZEV rules, neighborhood EVs are eligible for ZEV compliance credits of 1.25 in 2003, 0.625 in 2004-2005 and 0.15 thereafter. City EVs are eligible for somewhat more credit, depending on their range.[27]

The number of neighborhood and city EVs that have been, or soon will be, manufactured and sold is not insignificant. As of July 2000, Global Electric MotorCars (which was purchased by DaimlerChrysler in 2001) had produced more than 5,000 neighborhood electric vehicles.[28] Ford's Th!nk Mobility Group plans to manufacture as many as 10,000 neighborhood electric vehicles per year, and ran a 400-vehicle city EV pilot program in 2001 leading up to the Th!nk City's fall 2002 California launch.[29]

It is unclear how well city and neighborhood EVs can or will be integrated into Massachusetts' transportation system. The New York Power Authority is currently involved in a station-car trial project in which city EVs are leased to commuters for $199 per month. The cars can be recharged at commuter rail stations.[30] Similar programs are underway in other cities as well. Should this concept prove successful, Eastern Massachusetts, with its extensive network of commuter rail and subway lines, would be fertile territory for expansion of the program.

In sum, whether through the renewed production of highway-capable battery electric vehicles, the placement of larger numbers of low-speed city or neighborhood electric vehicles, or a combination of the two strategies, most major automakers are poised to meet the pure ZEV requirement in Massachusetts. Experience during the 1998-2000 memorandum of agreement period in California demonstrates that such levels of production are feasible.

Fuel-cell vehicles – like the Chrysler concept car shown above – may be a decade or more away from broad commercial viability, but the sale of small numbers of fuel-cell vehicles could go a long way toward complying with the ZEV program.
Photo: Electric Vehicle Association of Canada

Pure ZEVs: Fuel Cell Vehicles

Rapid advances in technology over the last decade have led automakers, government officials and many analysts to conclude that fuel-cell vehicles are the ZEVs of the future. While fuel cells are not expected to become commercially viable for the next decade or so, they can play an important role for automakers in meeting the pure ZEV requirement in the near term.

TABLE 5: LIGHT-DUTY FUEL CELL VEHICLES[31]

Manufacturer	Model	Body Style	Fuel Type	Development Stage	Projected Production Date
DaimlerChrysler	NECAR 4	Sedan	Hydrogen	Prototype	2004
DaimlerChrysler	NECAR 5	Sedan	Methanol	Concept	2004
Ford	FC5	Sedan	Methanol	Concept	2004
Ford/Th!nk	Focus	Sedan	Methanol	Demonstration	2004
GM/Opel	Zafira	Minivan	Methanol	Concept	2004
Honda	FCX-V1	Sedan	Hydrogen	Concept	2003
Honda	FCX-V2	Sedan	Methanol	Prototype	2003
Honda	FCX-V3	Sedan	Hydrogen	Prototype	2003
Mitsubishi	FCV	Sedan	Methanol	Concept	2003-2005
Nissan	Altra-based	Wagon	Methanol	Concept	2003-2005
Nissan	R'nessa	SUV		Concept	2003-2004
Toyota	FCEV RAV4	SUV	Hydrogen	Concept	2003
Toyota	FCEV RAV4	SUV	Methanol	Concept	2003

Fuel cells use hydrogen to create a chemical reaction that generates electricity to power a vehicle. Fuels such as gasoline and methanol can be used to generate the hydrogen needed, or hydrogen itself can be used as a fuel. When hydrogen is used, the only "emissions" from the fuel cell are water and heat. Other base fuels generate small amounts of hydrocarbon emissions (thus disqualifying them as pure ZEVs) but produce far less pollution than conventional vehicles because of their superior efficiency, and could receive AT-PZEV credit.

Until recent years, fuel cells have been mainly used in specialized applications such as space travel. But over the last several years, public-private partnerships at the federal level and in California have worked to bring fuel-cell vehicles to the demonstration stage. The California program, the California Fuel Cell Partnership, aims to demonstrate more than 70 fuel cell-powered cars and buses in the state by 2003.[32]

Automakers are already working toward the introduction of fuel-cell vehicles into their fleets. Table 5 lists light-duty fuel-cell vehicle projects currently being undertaken by auto manufacturers.

While hydrogen fuel cells could become the first pure ZEV to compete with battery electric vehicles, they suffer from the opposite problem as battery EVs. Battery EVs have the advantage of access to a broad power grid, but the disadvantage of lower range than conventional vehicles. Hydrogen fuel-cell vehicles, on the other hand, show promise of performing on a par with conventional vehicles, but suffer from lack of access to hydrogen as a base fuel. There are also many engineering issues that must be ironed out for fuel cells to become a practical mode of powering vehicles.

However, given the structure of the California ZEV program's credit scheme, fuel-cell vehicles do not need to be commercially viable in order to help automakers meet the requirement.

First, the ZEV program gives additional credits to vehicles based on their range. Pure ZEVs receive multipliers ranging from 1 for urban all-electric range of 50 miles or less to 10 for vehicles that get an all-electric range of 275 miles or more.[33] Ford's first-generation fuel cell vehicle, the Ford Focus FCV, is anticipated to have a range of 100 miles when introduced in 2004, but fuel-cell vehicles have already attained ranges of greater than 275 miles in testing.[34]

Second, the California ZEV rules allow manufacturers to take credit for vehicles placed in advanced technology demonstration programs, such as the California Fuel Cell Partnership, in addition to those vehicles placed in service.

Should automakers produce fuel-cell vehicles that attain a range of 275 miles, they would need to produce only one-tenth of the number of low-range battery-electric vehicles required under the program. Moreover, these vehicles could be placed in demonstration projects or with fleets, where infrastructure issues related to refueling would pose less of a problem. With every major automaker planning to have a fuel-cell vehicle ready by 2005, fuel cells could play a significant role in helping automakers meet the ZEV requirement.

AT-PZEVs: Hybrid-Electric and Natural Gas

Automakers have ample opportunities to fulfill the two percent AT-PZEV option through two already-viable technologies: hybrid-electric and natural gas vehicles.

- Hybrid-electrics are the only advanced technology vehicles being sold through the mass market nationwide. While existing hybrid-electrics such as the Toyota Prius do not yet qualify for AT-PZEV or PZEV credit, there is no technological reason why they cannot.[36] Production levels of hybrids indicate that those automakers with hybrid vehicles on the market in 2005 should be able to take full advantage of the AT-PZEV option.

- Compressed natural gas (CNG) vehicles have become increasingly popular in fleet applications. The number of CNG vehicles on the road nearly quintupled between 1992 and 2001 and now stands at more than 100,000. Four of the six major automakers sold CNG vehicles during model year 2001. Some CNG vehicles will be eligible for AT-PZEV credit.

HYBRID ELECTRICS

Hybrid-electric vehicles made their debut in the United States with the introduction of the two-seat Honda Insight in late 1999. Soon after, Toyota introduced the five-seat Prius. In calendar year 2000, the Prius and Insight sold a combined

TABLE 6: LIGHT-DUTY HYBRID-ELECTRIC VEHICLES[35]

Manufacturer	Model	Body	Fuel	Development Stage	Date Introduced/ Announced	Projected Production Date
DaimlerChrysler	Durango	SUV	Gasoline	Concept	Oct. 2000	2003
Dodge	Ram Pickup Contractor Special	Truck	Gasoline or Diesel	Prototype	Nov. 2000	2004
Ford	Escape	SUV	Gasoline	Demonstra-tion	Jan. 2001	2003
Ford	Explorer	SUV	Gasoline	Concept	Jan. 2001	2003
Ford	Prodigy	Sedan	Diesel	Concept	Dec. 1999	2003
GM	ParadiGM drive system	SUV /truck	Gasoline	Drive system for multiple body styles	Jan. 2001	2004
Honda	Civic	Sedan	Gasoline	Concept	Jan. 2000	2002
Honda	Insight	Coupe	Gasoline	Production	Dec. 1999	2000
Hyundai	Santa Fe	SUV	Gasoline	Prototype		2003
Toyota	Prius	Sedan	Gasoline	Production	June 2000	2000

9,300 units in the United States.[37] Worldwide, Toyota has sold at least 75,000 Prius vehicles since the vehicle's inception, and anticipates manufacturing 300,000 hybrids per year by 2005.[38]

Several other manufacturers are preparing to introduce hybrids to the American market. Honda estimates that it will sell an average of 2,000 of its new hybrid-electric Civics per month.[39] In fact, Japanese automakers are expected to introduce between 10 and 15 new hybrid models by the end of the 2003 model year.[40] As can be seen in Table 6 (previous page), at least six automakers have projected the availability of hybrid-electric cars by model year 2004. Should each of those automakers sell approximately 1,200 hybrids annually in Massachusetts, they will satisfy the AT-PZEV requirement through model year 2007. Additional credits could reduce those numbers further.

Months-long waiting lists for the Toyota Prius hybrid-electric vehicle (above) have led Toyota to increase distribution of hybrids to the United States. By 2005, the company expects to sell approximately 300,000 hybrids per year worldwide.
Photo: Electric Vehicle Association of Canada

Hybrid-electric vehicles have many advantages. Their performance and range is similar to that of conventional vehicles, while their fuel use and emissions are generally much lower.

However, hybrids also come with two downsides. First, while they generally achieve lower emissions and higher fuel efficiency than conventional vehicles, they are not the "transformative" technology envisioned by the original ZEV requirement. Second, none has yet been certified to receive AT-PZEV credit. Both the Honda Insight and the Toyota Prius meet the tough tailpipe emissions standards (super-low-emission vehicle, or SULEV, standards), but they do not yet meet the other requirements for PZEV credit, including zero fuel-related evaporative emissions and a 150,000-mile warranty for their emissions systems. Should automakers resolve these issues with hybrid-electric vehicles – which Nissan has already proven possible with its Sentra CA (see below) – hybrids could play a major role in fulfilling the AT-PZEV portion of the ZEV requirement.

Honda's natural-gas powered Civic GX is the first car to be certified to AT-PZEV standards.
Photo: NREL/DOE

CNG VEHICLES

Vehicles that operate on compressed natural gas also have the potential to receive credit toward compliance with the ZEV requirement. While largely limited to fleet applications, CNG vehicles have increased dramatically in popularity over the last decade, with the number of vehicles on the road increasing from 23,000 in 1992 to nearly 110,000 in 2001.[41]

To date, one CNG vehicle – the Honda Civic GX – has qualified for AT-PZEV credit. Several models of DaimlerChrysler Ram vans and wagons and Ford E- and F-Series pickup trucks meet SULEV emission standards, a major prerequisite for AT-PZEV credit.[42]

While the lack of public CNG refueling infrastructure has meant that only fleet operators could buy CNG vehicles, one should not underestimate the role fleet sales could play in helping manufacturers fulfill the ZEV requirement. In 2000, there were about 6.6 million automobiles and 6.1 million trucks in fleets nationwide. Government fleets accounted for approximately 13 percent of the cars and 39 percent of the trucks.[43]

Incentives or requirements for the purchase of alternative-fuel vehicles at the state and federal level have helped expand the use of those vehicles in government fleets over the last decade, and may be responsible for the rise in the overall number of CNG vehicles on the road.

In 1999, there were 827 CNG vehicles in use in Massachusetts.[44] Should CNG vehicle use continue to increase in Massachusetts at the 19 percent annual rate it did nationally between 1992 and 2001, manufacturers would sell at least 375 CNG vehicles in the state annually by model year 2005, or about 8 percent of that year's AT-PZEV requirement. (See Table 7) These projections are likely conservative. Even greater sales would be expected were there to be expanded refueling infrastructure for CNG vehicles, an issue to which we will return later in this report.

TABLE 7: CURRENT AND PROJECTED CNG VEHICLES IN MASSACHUSETTS AT 19 PERCENT ANNUAL GROWTH RATE[45]

Year	Vehicles in Use	Minimum Sales
1999	827	NA
2000	984	157
2001	1,171	187
2002	1,394	223
2003	1,658	265
2004	1,974	315
2005	2,348	375

PZEVs: Clean Conventional Vehicles

Both large and intermediate auto manufacturers will be called upon to make and sell significant numbers of vehicles that qualify for partial ZEV credit beginning in 2005 under the California ZEV rules or in 2004 under the northeast ACP. While the California MOA required automakers to produce significant numbers of battery-electric vehicles, no such requirement was in place for PZEVs. In addition, the number of PZEVs that will be required in Massachusetts in the near term is far larger than the number of pure ZEVs. As a result, the implementation of the PZEV standard puts automakers and the state in uncharted waters, relative to the pure ZEV requirement.

Nissan has demonstrated the ability of automakers to manufacture conventional cars that meet PZEV criteria with its Sentra CA. Nissan has combined several technologies to achieve the emission reductions and durability requirements of the PZEV standards, including: double-wall exhaust manifolds; a quicker warm-up catalyst; a new combustion control sensor; an electronically controlled swirl control valve that reduces cold- and warm-start hydrocarbon releases; and a specially coated radiator that converts ozone passing through the radiator into oxygen.[46] Nissan was expected to sell approximately 500 of the cars in 2000, though their distribution is limited to California.[47]

In its 2000 review of the ZEV program, CARB projected that automakers would have to take several steps to convert their cleanest gasoline-powered vehicles into PZEVs, including the installation of additional emission control hardware, sealed fuel systems or other systems to prevent evaporative emissions, and a commitment to repair emissions systems under warranty for 150,000 miles.[48] However, by October 2001, CARB had revised its assessment, claiming that attainment of PZEV standards would be less involved than previously thought. The cost of additional hardware, for example, is now estimated to be $60 to $85 per vehicle.[49]

TABLE 8: AUTOMAKERS' DEVELOPMENT OF ZEV-COMPLIANT VEHICLES[50]

	ZEV		AT-PZEV, PZEV, SULEV		
	Electric	Fuel Cell	Hybrid	CNG	Conventional
Honda					
Nissan					
Toyota					
DaimlerChrysler					
GM					
Ford					

Key:

- Vehicle in production
- Vehicle in limited production, sale to general public
- Vehicle in limited production, sale to fleets OR vehicle with limited capability
- Vehicle in demonstration phase
- Vehicle in prototype or concept phase OR manufacturer has produced in past
- No vehicle

In short, the production of large numbers of PZEVs may present logistical hurdles for automakers. The technology to achieve that goal, however, is clearly available.

Strategies for Compliance

The above analysis demonstrates that the aggregate sales requirements within the early years of the Massachusetts ZEV program are eminently attainable using existing or soon-to-be available technology. But not every major auto manufacturer is equally prepared to meet the ZEV requirements.

Manufacturers such as Ford and Toyota – which maintained production of electric cars after the end of the California MOA and have also invested in technologies such as hybrids and CNG vehicles – are in relatively good position to meet the program's requirements. Others – such as General Motors, which has no public plans to sell electric vehicles, is not scheduled to market a hybrid until at least 2004, and has no vehicles currently certified to SULEV emission standards – will meet the requirement only with difficulty. It is unclear how easy or difficult it will be for intermediate volume manufacturers, which have not yet been subject to any ZEV requirement, to make enough PZEVs to comply.

Automakers have claimed that there is insufficient lead time for them to produce enough PZEVs to meet the goals of the California requirement beginning in 2003.[51] Were that still to be the case by 2004, it would be expected that automakers would choose to abide by the original ZEV rules in Massachusetts, rather than attempt to market the significant numbers of PZEVs that would be required under the ACP. However, it is clear that the technology for the manufacture of PZEVs does exist and that vehicles are already being manufactured that meet the standard.

No automaker, however, can claim ignorance or insufficient notice with regard to Massachusetts' ZEV requirement. While there have been several changes to the ZEV program over the years, Massachusetts has resisted a decade of pressure from automakers to weaken or abandon the standard. Many major automakers now stand ready to fulfill their requirements.

Table 8 illustrates the various strategies the major automakers have taken toward the development of zero- and near-zero-emission vehicles. It should be noted that the information in this chart is based on data from federal and California government sources. Automakers may have other plans for development of vehicles that have not been disclosed to these sources, or may have been updated since their publication. Firms' PZEV and AT-PZEV readiness were based on compliance with SULEV emission standards – the main, though not only, technological hurdle for eligibility for PZEV credit.

Cost

One of the most frequently heard arguments against the ZEV requirement is that it is too expensive. The ZEV requirement in Massachusetts will undeniably impose new costs on automakers. However, those costs are reasonable within the context of the automotive industry and come after decades of strong profits by automakers – profits fueled in part by taxpayer subsidies of highways and oil and gas development and the assumption by the public of health costs stemming from automobile-related environmental pollution.

In its 2000 biennial review of the California ZEV program, CARB estimated the costs of technologies most likely to be used to comply with the pure ZEV, AT-PZEV and PZEV portions of the ZEV program – both in the short term, and in the long term once volume production has been achieved. In the short-term, CARB found that the cost to manufacture ZEV-compliant vehicles will range from $500 (since reduced to $200) for gasoline-powered PZEVs to $24,000 for freeway-capable electric vehicles with advanced nickel metal hydride (NiMH) batteries.[52]

However, the cost picture changes significantly when volume production (defined by CARB as 100,000 units or more) is achieved. With volume production, CARB estimates that the incremental cost of a four-passenger battery-electric car with an advanced NiMH battery will drop from $21,817 to $9,980. A similar car with a lead-acid battery would come at a cost premium of $2,848 – similar to today's hybrid-electric vehicles.

Applying CARB assumptions of the near-term incremental cost of complying with the ZEV requirement to estimates of the number of ZEV, PZEV and AT-PZEV vehicles required for Massachusetts under the program leads to the conclusion that construction of those vehicles would cost automakers $103.5 million under the Massachusetts ZEV program in the 2005-2006 model year timeframe, and significantly less under the ACP.

These costs are small when considered within the broader context of automakers' business operations. For example, the $103.5 million incremental cost of the current ZEV program represents:

- 0.9 percent of automakers' spending on advertising alone in the U.S. during 2000.[53]

- 0.7 percent of the $15 billion in sales by Massachusetts new-car dealers in 2000, 60 percent of which can be attributed to sales of new cars.[54]

- 0.4 percent of the net profits of the six major automakers during the last fiscal year for which complete data are available.

- 0.014 percent of the gross revenue of the six major automakers during the last fiscal year.[55]

This is likely a worst case scenario, as automakers have several opportunities to recoup some of their investment in the ZEV program.

First, the ZEV program creates some tangible financial benefits for automakers. The clean, highly efficient vehicles produced for the ZEV program will help automakers comply with Massachusetts' tough LEV II emission standards and national corporate average fuel economy (CAFE) standards – reducing the risk of costly fines for non-compliance. Moreover, work on alternative fuel vehicles can qualify automakers for government research and development assistance. Federal agencies involved in alternative-vehicle research, development and promotion requested budgets totaling $615 million in fiscal year 2001.[56]

Financial benefits will also accrue to automakers through the "spinoff" of EV technologies to other vehicle lines. Technologies developed for the Toyota RAV4-EV, for example, have been used in the popular Toyota Prius, while information gleaned from EV and hybrid development programs is likely to play an important role in the development of fuel-cell vehicles.[57] Finally, the manufacture of clean vehicles could improve automakers' corporate image. Toyota, for instance, has heavily marketed its Prius hybrid in an effort to bolster the firm's overall environmental image.

Finally, consumers could help defray the costs – or provide profit to automakers – depending on their willingness to pay more for ZEV-compliant vehicles. Many ZEV technologies provide additional value to consumers, particularly over the lifetime of a vehicle. Battery-electric vehicles, for example, generally cost less to operate than conventional vehicles, need less routine maintenance, have a quieter ride and can be conveniently recharged at home. One survey of California consumers found that about one-third of new car buyers would be "likely" or "very likely" to purchase an electric vehicle if the cost were similar to that of a conventional vehicle. Of those who expressed interest in purchasing an EV, more than two-thirds expressed willingness to pay a premium for an EV.[58]

In the case of AT-PZEVs, consumers have already demonstrated their willingness to pay a premium for hybrid-electric vehicles. The perception of lower lifecycle costs may play a role in this. CARB has estimated that fuel cost savings for hybrids would amount to $1,600 over the lifetime of the vehicle, assuming an after-tax gasoline cost of $1.75 per gallon – compared to an incremental cost for hybrids of $3,200.[59]

Consumers' willingness to pay is affected by much more than just utilitarian concerns. As the automakers' recent success in marketing sport utility vehicles indicates, a vehicle's image – and how it plays into a consumer's self-image – is critically important. Automakers' eagerness to create an image for clean cars that sells in the marketplace will thus play a significant role in customers' willingness to pay for the vehicles.

Summary

The Massachusetts ZEV requirement – with or without the northeastern ACP – is clearly attainable to automakers with existing technology. New technology, such as hydrogen fuel cells, could begin to play a role in the automakers' compliance strategy within the next three years. Attaining the goals of the ZEV requirement will not be easy for all automakers, but for most, the requirement can be met with a reasonable amount of effort. In addition, the ZEV requirement is unlikely to impose a significant financial burden on automakers.

CONSUMER READINESS

Provided that automakers can manufacture enough vehicles to satisfy the Massachusetts ZEV requirement, will anyone be interested in buying them?

While ultra-clean vehicles of the type required under the ZEV program have not yet been broadly marketed to the public, significant numbers of consumers appear ready to embrace cleaner cars. A 1997 national survey conducted by the Dohring Company found that more than 70 percent of consumers were interested or highly interested in reducing the amount of air pollution caused by their motor vehicles.[60] The enthusiastic response given to hybrid-electric vehicles since their introduction to the U.S. is yet more confirmation of consumers' willingness to purchase cleaner vehicles. Even battery-electric vehicles – long dogged by concerns about range and price – have shown strong appeal to the thousands who have had the opportunity to drive them in California and elsewhere, leading to continuing demand for electric vehicles that outstrips supply.

Combined with government policies that encourage the purchase of alternative-fuel vehicles by fleets, this consumer interest in cleaner cars should lead to healthy demand for ZEV-compliant vehicles in Massachusetts.

The California Electric Vehicle Experience

As noted earlier, automakers pledged to produce limited numbers of battery-electric vehicles for sale in California from 1998 to 2000 as part of an agreement with CARB to eliminate the ZEV percentage requirement until the 2003 model year. The memorandum of agreement (MOA) period is thus one of the few opportunities to gauge real-world consumer interest in battery-electric vehicles.

Unfortunately, it is also an imperfect gauge. Only two automakers, GM and Honda, offered battery-electric vehicles to the general population, with the rest of the manufacturers focusing on fleet sales. No manufacturer produced vehicles of the most popular type on the road: four-door five-passenger sedans. And those consumers who did attempt to lease battery-electric vehicles often faced an onerous task.

A Failure of Product or of Marketing?

Both GM and Honda assert that during the early portion of the MOA period their inventories of electric vehicles far outstripped consumer demand, and that the lack of demand demonstrates that EVs are niche-market vehicles at best. While there is little reason to doubt the automakers' claims of an initially tepid consumer response, there is ample reason to doubt their conclusion. Most EV purchasers during the MOA period were forced to surmount unusual obstacles to obtain their vehicles. Those who did succeed in obtaining them were generally pleased. And the demand for electric vehicles appears to have grown, both during the course of the MOA and afterward – despite a severe lack of vehicle availability.

Individuals were not generally permitted to purchase EVs during the MOA period, even from GM and Honda. EVs were provided by those manufacturers through a three-year lease. Some leases came with restrictive 10,000-mile annual limits. Consumers testifying before CARB's 2000 biennial review of the California ZEV program cited sales staff who were unfamiliar with the vehicles, long delays in getting information, lack of clarity about their status on "waiting lists," and long delays in obtaining vehicles once orders were placed.[61]

One owner of a General Motors EV1 described the process this way:

> In order to drive an electric vehicle from a major automaker, you first have to get over the fact that you have to lease it. Then you have to figure out where you can get one. Then you have to wade through a raft of salespeople who would much rather have you purchase a gas car. . . . Once you do manage to get a hold of the right person, you have to prove to them that you can live with the "limitations" of an EV. After you have done this, you're allowed to be put on the waiting list for a car.[62]

A 2000 survey of California consumers conducted for the nonprofit Green Car Institute demonstrates that the initial lack of consumer demand for EVs during the MOA period could have as much to do with poor choices by automakers as with concerns about EVs themselves.

The survey found that about one-third of California new car buyers would be "likely" or "very likely" to purchase an electric vehicle if the cost was similar to a conventional vehicle. Yet the survey also showed that those consumers would be turned off by policies similar to those used by automakers during the MOA period. For example, less than 27 percent of these "EV intenders" expressed interest in purchasing the types of vehicles offered by manufacturers during the MOA period – compact pickups, sub-compact sedans or coupes, sports cars, minivans and compact SUVs. [63] Another 40 percent said they would opt to purchase a gasoline vehicle if leasing was the only option for obtaining an EV, as was the case during the MOA period.[64]

These results – along with anecdotal reports of consumer difficulty in obtaining EVs – indicate that automakers' manufacturing and marketing decisions were not properly designed to capture the maximum market share in California during the MOA period. Automakers cannot reasonably claim that the MOA period was a fair test of the marketability of EVs to the general public.

Consumer Response

Several surveys of electric vehicle owners in California show that EV drivers were generally satisfied with their experience – once they succeeded in obtaining vehicles.

One such study was conducted by the California Mobile Source Air Pollution Reduction Committee (MSRC) of 294 electric vehicle owners in March 2000. The survey found that:

- 80 percent of those surveyed were more satisfied with their EV than with their current gasoline car.

- 70 percent said they use their EV as their primary vehicle (93 percent of those had access to another vehicle).

- 74 percent said they use their EV more than three-quarters of the time. Only 46 percent said they expected to use their EV that much before taking ownership.

- 77 percent would lease another EV.[65]

Other studies cited by CARB in its 2000 biennial review found similar results.

- Almost 70 percent of California state employees who rented EVs through a state rental program said they would consider buying or leasing an EV, with many noting that EVs were easy to drive and performed well.

- Southern California Edison, which has put more than 4.5 million miles on more than 420 EVs, found that operating EVs is less costly than operating gasoline vehicles due to lower fuel and maintenance costs.

- 84 percent of public-sector fleet EV operators surveyed by Southern California Edison said they were satisfied with the performance of their EVs, and 96 percent of the agencies expressed interest in expanding their EV fleets.[66]

The results of these surveys indicate that the vast majority of those who have driven EVs in California have been satisfied with the experience. While some of those surveyed cited the vehicles' limited range as a concern, the results of the MSRC survey indicate that EVs served individuals' real-life driving needs better than most drivers had anticipated when they obtained the vehicles.

Demand But No Supply

The satisfaction of early EV owners in California and growing public awareness of EVs has led to continued interest in EVs in California, even after many automakers involved in the MOA curtailed production of electric vehicles.

In its 2000 biennial review of the ZEV program, numerous individuals and fleet operators testified that they wished to purchase additional EVs, but had been unable to do so. Among those wishing to purchase or lease EVs were:

- Lessees of GM's EV1, which was the subject of a safety recall by the automaker. Lessees reported that they had been unable to lease another EV, either from GM or other automakers.

- Representatives of 14 corporate and governmental fleets.

- Southern California Edison, which had planned to put an additional 200 EVs per year into its fleet.

- CARB itself, which has been unable to obtain enough electric vehicles for its programs to place EVs with government agencies.[67]

In written testimony submitted to CARB for its 2000 review, Lisa Rawlins, an executive with Warner Brothers studios, detailed the company's frustrations with attempting to obtain EVs.

> DaimlerChrysler informed us that they were "sold out" of the EPIC electric minivan and would not be producing more until 2002. . . . Toyota informed us that their RAV-4s are all committed. . . . Nissan told us that their Altra EV is sold out for this year and that they have a long waiting list should any become available. . . . Ford told us that they may have a couple of Ranger EVs with nickel-metal hydride batteries left in the state, but they were only available at one dealer in Ventura. . . . We contacted Honda . . . (a)gain, we were told that we could be added to an already long waiting list . . .

Rawlins said that at least 50 employees of Warner Brothers identified themselves as seriously interested in buying or leasing electric or other clean vehicles. "To say that we were frustrated by the lack of product and unresponsiveness of the automakers is an understatement," she said.[68]

Another informal survey identified California fleet buyers interested in purchasing up to 9,000 additional EVs over the next several years.[69]

While there can be no guarantee that the Massachusetts market will directly mirror that of California, a similar public response can be expected. It is also important to recall that the number of EVs to be sold in Massachusetts in the short-term – fewer than 3,500 by 2007 under the original ZEV rules – can be satisfied through the development of niche markets, such as fleets and "early adopters," rather than a general market.

The California MOA experience suggests that automakers did not allocate sufficient time and resources to nurture the development of a market for a relatively new technology, but instead opted to cut their losses after a period of only a few years when the specific requirements of the MOA had been met. If this was indeed the case – and the above predictions of consumer interest in EVs hold true – it would make a strong argument for the necessity of steadily increasing EV sales requirements to create a stable market in Massachusetts.

Clean Vehicles in Fleets

Massachusetts

Massachusetts is not without its own experience with alternative vehicles. The state Division of Energy Resources (DOER) has run an electric vehicle demonstration program since 1992 in which commuters have logged more than 200,000 miles in electric vehicles leased through the state. During the program's peak, from 1995 to 1998, a fleet of 31 vehicles was available for lease.[70] DOER reported that most of the participants' expectations for vehicle performance had been met and that many lessees expressed their desire to continue leasing an EV. A cumulative survey found that drivers ranked the performance of EVs 7.6 on a scale of 10.[71]

In addition, since 1996, state agencies have been governed by an executive order that mandates ("to the extent available and practical") the procurement of alternative-fuel vehicles.[72] While similar to the federal Energy Policy Act of 1992 (EPAct), which includes requirements for fleet purchases of alternative-fuel vehicles, Massachusetts' standards are stronger. Unlike the federal program, which allows the purchase of bi-fuel vehicles (those that can run on gasoline or an alternative fuel), Massachusetts has focused on the purchase of dedicated alternative-fuel vehicles. Moreover, Massachusetts requires that a certain percent of all state vehicles purchased be zero-emission vehicles. Since 1997, the percentage of alternative-fuel vehicles required has increased from 10 percent of new purchases to 75 percent, and the percentage of zero-emission vehicles from zero to 10 percent.[73]

Between 1997 and 2001, the state purchased a total of 1,560 vehicles, of which 381 fit the looser federal definition of alternative fuel vehicles. Many of those vehicles are dedicated CNG vehicles and electric vehicles such as Ford Ranger pickup trucks. No systematic study has been conducted of how those vehicles performed. However, Eric Friedman, director of state sustainability for the Massachusetts Executive Office of Environmental Affairs, reports that many drivers enjoyed operating EVs, but that there were concerns about vehicle range. Friedman indicated that the biggest problems of the program have been the lack of CNG fueling infrastructure and the lack of availability of electric vehicles from manufacturers.[74] In addition, the state has recently let a contract facilitating the purchase of hybrid-electric vehicles by state agencies.

Should the EV availability problem be solved and modest improvements made in CNG fueling infrastructure, the state could be a significant customer for automakers seeking to comply with the ZEV requirement. If the state continues to purchase nearly 400 vehicles per year for its fleets, as it has over the last four years, the terms of the 1996 executive order would dictate that at least 40 of those vehicles would be pure ZEVs and that another 260 would run on other alternative fuels. Those numbers may not appear large, but the pure ZEV purchases alone would represent 4 percent of the automakers' pure ZEV requirement for the 2005 model year. That number could be expanded should municipal, institutional and business fleets follow the state's lead and incorporate significant numbers of clean vehicles.

Other States

Evidence from state and local fleets across the country indicates that alternative-fuel vehicles can be a particularly good fit with fleet operations.

The U.S. Department of Energy's National Renewable Energy Laboratory conducted two 1999 surveys – one of city and state fleet drivers and one of fleet managers – in an effort to gauge reaction to a host of alternative fuel vehicles.

Fleet managers reported the following:

- Fleets with electric and E85 (ethanol) vehicles as their primary alternative fuel vehicle types reported the highest percentages of satisfaction of any alternative fuels. More than 60 percent of state fleet managers and 40 percent of city fleet managers reported being "very satisfied" with their electric vehicles.

- Most fleet managers indicated that drivers wanted to drive electric vehicles.

- More than 80 percent of state fleet managers reported receiving an equal number of complaints about EVs as about gasoline-powered vehicles. Equal numbers of managers reported receiving more complaints or fewer complaints about EVs than conventional vehicles.

- Fleet managers were less satisfied with the CNG vehicles in their fleets, although satisfaction levels were higher for vehicles made by original equipment manufacturers than for vehicles subjected to after-market conversion to CNG power.[75]

Fleet drivers reported the following:

- Among city drivers, 96.2 percent of dedicated CNG vehicle drivers rated overall performance as excellent or very good, as did 66.7 percent of EV drivers. Among state fleet drivers, 85 percent rated performance of their dedicated CNG vehicles as excellent or very good and 58 percent reported overall performance of their electric vehicles as excellent or very good.

- Among city fleet drivers, 66.7 percent said they were "very satisfied" with their EVs and 38 percent were very satisfied with their dedicated CNG vehicles. Among state fleet drivers, 41.9 percent said they were "very satisfied" with their electric vehicles and 38.5 percent were very satisfied with their dedicated CNG vehicles.

- Nearly all state and city fleet EV drivers, and more than half of dedicated CNG vehicle drivers, would recommend an alternative-fuel vehicle to others.[76]

The Rush for Hybrids

No development in recent years demonstrates more clearly the demand for cleaner cars than the rush by consumers to snap up the first generation of hybrid-electric cars sold by Honda and Toyota beginning in late 1999.

Consumer demand for hybrid vehicles has been strong from the very start. Toyota, which has been marketing its hybrid Prius in Japan since 1997, received nearly 1,800 orders for the vehicles from its Web site before a single Prius had arrived in a dealer showroom.[77] Demand was also strong for the Honda Insight, a two-seater with less broad market appeal than the five-seat Prius. Demand for both vehicles spawned waiting lists that, in the Boston area, led to delays of five to six months for delivery of Toyota Prius models by the summer of 2001.[78]

Within 18 months of their introduction to American consumers, both Honda and Toyota had taken steps to increase the availability of hybrid vehicles, with Honda increasing Insight availability by more than 50 percent for the 2001 model year and Toyota increasing the U.S. allotment of Prius cars by more than 40 percent.[79]

The demand for the Prius and Insight could be just the tip of the iceberg. A recent J.D. Power and Associates report found that 60 percent of new vehicle buyers would consider buying a hybrid-electric vehicle. Nearly one-third of those said they would still buy a hybrid even if the added cost of the vehicle was not fully offset by fuel savings.[80]

Automakers are clearly confident that sustainable demand exists for hybrid-electrics. Honda has already announced the production of a hybrid version of its popular Civic small car, Toyota is planning to ramp up production of its hybrid models, and several American auto manufacturers are nearing introduction of their own hybrids. John Wallace, executive director of Ford Motor Company's Th!nk Group, has said he expects to see as many as a million hybrid-electric vehicles being sold worldwide by the middle of the next decade.[81]

If they are correct, hybrid-electric technology could give automakers a clear way to satisfy the AT-PZEV or PZEV portions of the ZEV requirement, provided that they invest in the additional evaporative emission controls and enhanced warranties needed to meet PZEV criteria. The initial enthusiasm consumers have shown toward the Insight and the Prius – even at a time of low gasoline prices – augurs well for the sales of hybrid-electrics in the future.

Pricing

One factor that will inevitably affect consumer demand for ZEVs is price. For the majority of vehicles covered by the ZEV program, price is unlikely to be a major deterrent to consumer purchases. Even for more-expensive electric vehicles, automakers will have strong incentives to keep prices within reach of consumers. Massachusetts consumers are also unlikely to see broad increases in new car prices as a result of the program.

The issue of pricing is very different from the issue of automaker cost. While the cost of new technologies to automakers is fixed (at least in the short term), pricing is a result of strategic decisions by automakers designed to achieve specific goals within a given marketplace. Automakers may set pricing to move product, to maximize short- or long-term profits, to improve reputations, or to gain competitive advantage.

With regard to PZEVs, whose incremental cost of manufacture is small, consumers are unlikely to see a significant difference in price versus conventional cars. Nissan, for instance, has decided not to recoup the incremental costs of its Sentra CA PZEV from California consumers.[82] As noted above, consumers have already demonstrated a willingness to pay more for hybrid-electric vehicles due to their lower lifecycle costs.

For electric vehicles, automakers' pricing decisions will depend on their time horizon for earning profits from the vehicles. The Green Car Institute, in a study of future EV pricing, posed three scenarios based on automakers' previous marketing efforts with new vehicle lines. To break even on their investment within five years, manufacturers would need to charge approximately $37,000 to $42,000 for their electric vehicles.[83] Two other scenarios, in which the price of EVs eventually reaches $27,000, would bring significant short-term losses, but would build volume. The study's authors concluded that pricing a vehicle initially at $20,000, with the price gradually rising to $27,000, would bring about sufficient volume that manufacturers could begin to make money on each vehicle sold by year five.[84]

An automaker seeking to maximize long-term profits and gain position in the EV market, then, would choose not to pass on the full costs of EVs to consumers in the short run, choosing instead to build volume. Once volume production is reached, the incremental cost of each vehicle falls, and profitability becomes possible at a lower price than would otherwise be the case. Because the ZEV program will require higher numbers of pure ZEVs in future years, such a strategy appears to be a more rational course than producing limited numbers of EVs at break-even prices in the short term.

In its initial marketing of the RAV4-EV to the public, Toyota appears to be steering a middle course. The list price of the small SUV, which is to be distributed in California, is $42,000, but a $9,000 credit from CARB and the $3,000 federal tax break reduces the cost to consumers to $30,000, which includes an in-home charging device.[85] Toyota, it should be noted, faces no competitive pressures in the EV market at present, since it is the only major automaker selling EVs directly to consumers.

Of course, there is another option for automakers to recover the cost of ZEV production through pricing: increase the prices of all their products. In response to CARB's January 2001 proposed changes to the ZEV requirement, General Motors submitted a report by National Economic Research Associates and Sierra Research, Inc. that claimed automakers would spread the costs of the ZEV requirement across all their California vehicles, resulting in significantly higher prices for consumers. Using different figures but the same basic assumptions, CARB estimated the increase at only $36 per vehicle.[86] However, CARB also questioned why automakers would only choose to spread the costs to California vehicles, and, more fundamentally, whether automakers would have the freedom to raise prices *at all* in a competitive marketplace. An automaker that chose not to pass on the increased costs of ZEV production would presumably gain a competitive advantage in the automotive marketplace over one that did.

The competitiveness of the automotive market, therefore, limits the degree to which consumers will face increased overall vehicle prices as a result of the ZEV requirement. The prices of vehicles covered by the requirement will depend on strategic decisions by automakers and the complex workings of the market, but automakers would have substantial incentives to keep prices of ZEV-compliant vehicles low in the short term.

Incentives

To the extent that ZEV purchasers are asked to pay more for their vehicles, federal and state incentives can also help consumers defray those costs.

Federal incentives include tax deductions of $2,000 to $50,000 for purchase of clean fuel cars, trucks, vans and buses. Deductions for clean fuel passenger vehicles are $2,000. In addition, a tax deduction of up to $100,000 per location is available for installation of refueling or recharging stations by businesses. The federal government has also offered a tax credit of up to 10 percent of purchase price or $4,000 toward the purchase of electric vehicles. This tax credit, however, is in the process of being phased out, and will end entirely in 2005.[87]

At the state level, Massachusetts offers businesses rebates of up to $2,000 to offset the incremental cost of purchasing an alternative fuel vehicle. Private energy companies, such as Keyspan Energy Delivery, also provide technical assistance and may provide financial incentives for fleets to convert to natural gas.[88]

Summary

Massachusetts consumers appear ready for the ZEV program and, together with fleet purchasers, should provide a substantial market for the vehicles once introduced.

- The California experience with electric vehicles has shown that EVs are highly attractive to specific segments of the motor vehicle consumer base – particularly those with strong concern for the environment or a propensity to be “early adopters” of technology. These users have demonstrated their willingness to make significant sacrifices in order to obtain EVs, and their numbers are significant.

- The experience of electric vehicle drivers has been generally positive, and most would lease or buy another EV or recommend it to others. Fleet experience with EVs and CNG vehicles has also been generally positive, although some concerns remain. Overall, in the places where clean vehicles have been introduced, they have fared well.

- The initial surge in demand for hybrid-electric vehicles in Massachusetts and elsewhere – and the continuing demand for battery-electric vehicles – is an indication of the strong consumer preference for clean, efficient cars, and suggests that consumers will purchase ZEVs in the numbers required by the program.

- Lack of availability has been the primary drag on the development of an electric vehicle market, while infrastructure concerns have reduced the attractiveness of CNG vehicles. The California MOA experience proves that manufacturers will only supply EVs in the short run with a government requirement.

- Price is unlikely to be a substantial obstacle to consumers wishing to purchase ZEV-compliant vehicles or other new automobiles in Massachusetts.

In addition, as noted in the previous section, experiments with city and neighborhood EVs could create new markets for the vehicles in years to come.

INFRASTRUCTURE READINESS

Unlike California, which has taken great efforts to expand alternative-fuel infrastructure over the last decade, Massachusetts has relatively few alternative-fuel refueling stations and public electric vehicle charging stations. As of 2000, Massachusetts had but 15 CNG refueling stations and three public electric charging stations.[89]

Creating alternative-fuel infrastructure in Massachusetts will be a challenge, but it need not prevent the state from reaching successful compliance with the ZEV requirement. For one thing, only a small percentage of the vehicles covered by the ZEV program even require access to alternative fuels – the vast majority of the requirement can be satisfied with hybrid-electric and conventional vehicles that run on ordinary gasoline.

For those vehicles that are powered by alternative fuels, California and New York have established themselves as models for the quick development of refueling infrastructure. The establishment of electric vehicle charging stations is relatively inexpensive, and standardization of charging mechanisms will likely lead to further reductions in price. CNG fueling infrastructure is more expensive, but strategic decisions on the location of CNG fueling stations – combined, perhaps, with financial help from the natural gas industry – could lead to Massachusetts having sufficient CNG fueling infrastructure in place within the next several years.

Electric Vehicle Infrastructure

One of the most significant benefits of electric vehicles is their ability to be recharged overnight at home – in effect, giving drivers a "full tank" each morning without ever having to visit a filling station. However, many electric vehicle owners also want the convenience and added range provided by public charging stations. Unlike gasoline filling stations, public EV charging stations tend to be placed in locations where cars sit idle for long periods of time: shopping centers, places of employment, and commuter parking lots.

RESIDENTIAL RECHARGING

The cost to install home charging stations for electric vehicles is generally not great. According to CARB, conductive charging systems are likely to cost between $700 and $1,400, now that they have been chosen by CARB as the standard charging system for EVs. Installation costs typically run less than $1,500. Auto manufacturers in California have often included chargers with the EVs they lease or provided grants to help defray the cost, and Toyota is currently including home charging devices in the sticker price of its RAV4-EV.[90]

The essential components of an EV charging system include electrical service to the site, on-site wiring, and the EV charging equipment itself. There are several types of EV charging equipment, each with different requirements. Some deliver AC current directly to the vehicle, while others rely on equipment to convert household electricity to DC current. Some include conductive chargers that convey electricity through metal-to-metal contact, while others charge through magnetic induction of electricity. All must include features to ensure safety during operation.[91] The type of charging system used then dictates any changes in wiring and electrical service that must be made.

In the past, automakers were evenly split in their support for inductive and conductive charging systems, leading to consumer confusion, added investment in multiple public recharging platforms, and limited prospects for volume production. CARB's 2001 choice of on-board conductive charging as the standard charging system for EVs (effective in 2006) will resolve many of these problems and should ease the installation of both public and private charging infrastructure.

Residential recharging stations can also be installed quickly, generally with seven to 10 days lead time.[92] Complications can arise when residential sites do not have the minimum electrical capacity needed to support EV charging, but most single-family homes have sufficient capacity for overnight EV charging.[93]

Residential charging of EVs also requires the development of a regulatory framework to ensure public health and safety. The Massachusetts

Electrical Code governs the installation of electric vehicle charging equipment in every municipality of the state.[94] Installation of EV charging equipment requires the involvement of local wiring inspectors and utilities. The electrical code also dictates siting and other conditions for the installation of chargers – conditions that might necessitate additional costs for homeowners such as improved lighting or running electrical conduits to outside garages not currently connected to electrical lines.

In short, the installation of EV recharging is possible for most owners of single-family homes in Massachusetts at a reasonable cost, relative to the cost of the vehicle. Those costs should continue to decline over time and can be offset by manufacturer rebates and, perhaps in the future, incentives or off-peak electric pricing from electric utilities.

PUBLIC RECHARGING

Many, though by no means all, electric vehicle users turn to public recharging stations to extend the range of their vehicles. A 1998 survey of California electric vehicle users found that 46 percent use public charging at least once a week while 37 percent rarely or never use public charging stations.[95]

As noted above, Massachusetts has only three public EV charging stations. In addition, the state has 22 other charging stations for government, private and public use, not including home recharging stations.[96]

The installation of additional public charging capacity can, however, be done quickly and at reasonable cost. Public EV charging stations can be installed for approximately $5,000 to $7,000 at new construction sites or $10,000 at existing sites. The cost for installing additional chargers at a single site is significantly lower.[97] As is the case with residential installations, sufficient electrical capacity must exist to support the chargers.

California has shown that it is possible to create public charging infrastructure in a relatively short time-frame. From 1997 to 2000, the number of EV charging stations in the state jumped from 197 to 335, a 70 percent increase.[98] Because EV recharging practices are so different from gasoline refueling, it is difficult to place a number on how many public charging stations would be needed in Massachusetts.

In California, the cost of electric charging stations has generally been covered by a combination of station owners, automakers, local governments and state government funds through the Petroleum Violation Escrow Account and the U.S. Department of Energy Clean Cities grant program.[99] Additional potential for funding exists through the federal Congestion Mitigation and Air Quality (CMAQ) program, which provides funding for projects that reduce vehicular air pollution. In addition, businesses that install electric vehicle charging stations can be eligible for federal tax deductions of up to $100,000.

Private businesses may also have incentives to create public charging opportunities. Costco wholesale stores, for instance, have installed EV charging stations at more than 50 stores in California, Florida, Arizona and Hawaii.[100] Provision of EV charging opportunities by retailers is an additional perk to customers, particularly those who drive long distances to reach a store. Employers could also provide EV charging – however, this would be effective only for employers that have significant numbers of EV-driving employees, or for those that use EVs in their fleets. Electric utilities could also play a role in helping to expand EV infrastructure.

Clearly, there is no technological barrier to the erection of a sufficient public EV charging infrastructure in Massachusetts within the next several years, and there are many potential sources of funding – both public and private – for the construction of EV charging facilities. State funding for alternative-fuel infrastructure development (beyond the infrastructure needed for state fleets) would be beneficial, but is unlikely to be substantial at a time of budgetary shortfalls.

The state can, however, play a critical role by demonstrating leadership in the development of EV infrastructure. The development of a comprehensive plan is necessary to ensure that public and private money spent on EV charging infrastructure is invested wisely. The state can also play an important role by using federal funds to leverage additional private investment in charging infrastructure.

Efforts such as the U.S. Department of Energy's Clean Cities program provide a good model for how the public and private sectors can work together to promote alternative fuel vehicles and the development of refueling infrastructure. However, the ultimate responsibility for leadership rests with the state.

Natural gas fueling stations like the one above can be expensive to install, but strategic location of fueling stations could expand the market for CNG-fueled vehicles.
Photo: DOE/NREL

CNG Vehicles

The construction of CNG refueling infrastructure poses different problems than EV recharging. Because CNG vehicles are refueled in a similar fashion as conventional vehicles, the need exists for centralized refueling facilities – either private ones for fleets or "natural gas stations" for the public.

Currently, Massachusetts has about 15 CNG fueling sites, almost all of them inside Interstate 495.[101] Surveys of city and state fleet alternative-fuel vehicle drivers indicate that fueling stations must be within five miles to be considered convenient.[102] The California Energy Commission projects the need for 2,500 CNG fueling stations in that state.[103] Applying these two figures to a state the size of Massachusetts, the state would ultimately need somewhat more than 100 CNG fueling stations statewide to attain full coverage.

The cost of building a CNG fueling station can be high. Fast-fill stations of mainstream size cost approximately $500,000 to construct, with public access stations significantly more expensive than private-access ones.[104] The high costs of CNG refueling stations have generally limited construction to firms with CNG fleets that can refuel centrally and natural gas suppliers.

However, there is significant potential for the expansion of public and fleet CNG infrastructure. In New York State, state officials have used money from an environmental bond act to support the construction of alternative fuel infrastructure for state fleets. The plan includes a network of large fueling stations surrounded by 30 smaller stations for mid-day fill ups.[105] Through March 2000, the state had committed approximately $2.5 million for the installation of CNG infrastructure for state fleets, including the 30 fueling stations.[106]

The availability of fueling infrastructure has helped further the successful expansion of alternative-fuel vehicle use by creating "clean corridors" through which CNG vehicles can travel statewide. Since 1997, New York State has purchased more than 1,300 CNG vehicles for state fleets – a figure greater than the *total* number of CNG vehicles on Massachusetts' roads in 1999 – along with more than 150 electric vehicles. At present, more than 2,000 of the approximately 13,000 vehicles in the New York State fleet are alternative-fueled vehicles; the majority of them powered by CNG.[107]

New York State has also led the way in the development of public CNG fueling infrastructure. In 2001, the state entered into a public/private partnership that will result in the construction of 16 high-volume CNG fueling stations on state-owned lands. The stations will be open to the public. State officials estimate that the program, in which a private vendor will install, operate and maintain the stations, will save taxpayers $3 million.[108]

Massachusetts is making its own attempts to expand CNG fueling infrastructure. A coalition of state and regional agencies has applied for federal CMAQ program funding to build as many as 12 new public CNG fueling stations, most of them inside the Interstate 495 belt. Should the plan be approved, Eastern Massachusetts would have among the densest CNG fueling infrastructure in the eastern U.S. Five of those stations could be in place by the fall of 2002.[109]

Another promising development is the potential for home-fueling systems that would enable homeowners to fuel their CNG vehicles directly from their home gas lines. Last year, Honda – manufacturer of the Honda Civic GX natural gas vehicle – purchased a 20 percent interest in FuelMaker, a manufacturer of natural gas vehicle fueling appliances. Honda hopes to assist the company with the development of an inexpensive home refueling system for natural gas vehicles.[110]

As with electric vehicle recharging, sources of public and private funding exist for the construction of CNG fueling stations. While the cost of CNG fueling facilities may be high, wise decisions on the location of those stations will be a key to their success. Again, the success or failure of infrastructure development depends on leadership. Massachusetts should look to New York State for an example of how to bring leadership to bear to solve the CNG infrastructure problem.

Summary

Refueling infrastructure – especially for alternative fuel vehicles such as electric and CNG vehicles – represents one of the most significant obstacles Massachusetts must overcome in the successful rollout of the ZEV program. It is important, however, to put that obstacle in perspective: more than one-third of the EV drivers in the California survey claim to rarely or never use public charging, while hundreds of CNG vehicles currently operate in Massachusetts with only limited refueling opportunities. The addition of more fueling infrastructure, however, will dramatically expand the number of individuals, private fleets and government agencies that can fit alternative-fuel vehicles into their transportation plans. A relatively small number of facilities can go a long way to facilitating development of the market.

The good news is that Massachusetts can create the necessary public infrastructure for electric and CNG vehicles by the year 2005. Neither the costs nor the lead time need be prohibitive. Government, businesses and vehicle owners all have roles to play in promoting infrastructure development. But the state must have a plan for the creation of alternative fuel infrastructure and support it with judicious application of funding from federal and state sources. Local public-private partnerships can help, but ultimately, the responsibility for leadership rests with the state.

Conclusion and Recommendations

Massachusetts' Zero-Emission Vehicle program is a desirable public policy that will reduce pollution caused by automobiles, enhance the state's energy security, and encourage the development of even cleaner vehicles in the future. It is also a viable public policy, given the technological advances in clean car technology over the past decade, consumer demand for clean vehicles, and the potential to create the necessary infrastructure to support the program in the near term.

The state of Massachusetts has the power and the time to maximize the positive impact of the ZEV program in the years before it goes into effect. To achieve this goal, the state should take the following actions.

Massachusetts should retain its commitment to the introduction of significant numbers of ZEV and near-ZEV vehicles by the middle of this decade.

The current ZEV program, as amended by California in 2001, is clearly realistic for Massachusetts. The current ZEV program has the advantage of getting significant numbers of pure ZEVs and advanced technology vehicles on the state's roads within the 2005-2006 timeframe, enabling markets for these vehicles to build more quickly than under the northeastern ACP.

By offering the ACP, Massachusetts risks further delays in the introduction of the transformative technologies envisioned by the original ZEV program – electric, fuel cell and alternative-fuel vehicles. This risk may be worth taking if it leads to consensus among clean car advocates, state officials, and automakers with regard to the future course of the ZEV program. The federal lawsuit filed in February by DaimlerChrysler and General Motors against New York State, however, shows that such consensus does not exist.

History shows that *no* formulation of the ZEV program is likely to be fully embraced by all the automakers, some of which appear to have committed to a strategy of fighting any ZEV requirement in court, regardless of the cost. Yet, history also shows that a strong ZEV requirement can motivate automakers and others to make a quantum leap in clean vehicle technology. To hasten the development and deployment of that technology, Massachusetts should commit itself to the strongest available version of the ZEV program.

Massachusetts should take leadership in the development of infrastructure for alternative vehicles.

The state can play an important role in the development of alternative fuel infrastructure. State officials should provide leadership by working with multiple stakeholders to devise an alternative fuel infrastructure plan for the state. Commitments of public resources should be directed to areas of strategic importance to the plan, and should be used to leverage private investment in alternative fuel infrastructure. California and New York have demonstrated that state leadership in infrastructure development can pay dividends; Massachusetts should follow their lead.

Massachusetts should encourage and assist in efforts to educate the public about the benefits of cleaner vehicles.

Public awareness of the ZEV requirement in Massachusetts is low, but a public education plan leading up to the launch of the ZEV program could play a key role in the program's success. Such a program should not only clearly extol the environmental benefits of ZEVs, but should also deal with common consumer concerns, such as worries about vehicle range and safety. The allocation of state resources to this effort would be beneficial, but there are also other public and private resources that can be leveraged for this effort.

Massachusetts should retain its goals for state purchases of alternative fuel vehicles and zero-emission vehicles.

Problems with a lack of alternative fuel infrastructure and a lack of electric vehicle supply have hampered the state's efforts to comply with the 1996 executive order mandating state purchase of alternative-fuel vehicles. Assuming that these problems are resolved (as New York

State has demonstrated they can be with regard to infrastructure), Massachusetts should continue to demonstrate its leadership by maintaining the aggressive 1996 goals.

APPENDIX: GLOSSARY OF ABBREVIATIONS

ACP – Alternative compliance plan for the ZEV program negotiated by northeastern states.
AT-PZEV – Advanced technology partial zero-emission vehicle credits.
CAFE – Federal Corporate Average Fuel Economy standards.
CARB – California Air Resources Board. Body charged with setting vehicle emissions standards in California.
CMAQ – Federal Congestion Mitigation and Air Quality grant program.
CNG – Compressed natural gas.
CO_2 – Carbon dioxide.
DEP – Massachusetts Department of Environmental Protection
DOER – Massachusetts Division of Energy Resources.
E85 – Fuel with 85% ethanol.
E95 – Fuel with 95% ethanol.
EPAct – Energy Policy Act of 1992, requires some fleet purchases of alternative-fuel vehicles.
EV – Battery-electric vehicle.
LEV II – Low-Emission Vehicle II program adopted by Massachusetts in 1999. Includes stringent limits on emissions from light- and medium-duty vehicles beginning in 2004 and includes the ZEV requirement.
LNG – Liquid natural gas.
LPG – Liquid petroleum gases, also known as propane.
M85 – Fuel with 85% methanol.
M100 – Fuel with 100% methanol.
MBTA – Massachusetts Bay Transportation Authority.
MOA – Memorandum of Agreement negotiated between CARB and six major automakers in 1996 that eliminated interim ZEV requirements for 1998-2003 model years.
MTBE – Methyl tertiary butyl ether, a gasoline additive.
MSRC – California Mobile Source Air Pollution Reduction Committee.
NiMH – Nickel metal hydride batteries.
NO_x – Nitrogen oxides.
PbA – Lead-acid batteries.
PM_{10} – Particulate matter under 10 microns in diameter.
PZEV – Partial zero-emission vehicle credits.
SULEV – Super-low-emission vehicle; the second-cleanest emission bin under the LEV II program and a prerequisite for qualification for PZEV credit.
SUV – Sport utility vehicle.
VOC – Volatile organic compounds.
ZEV – Zero-emission vehicle.

NOTES

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[3] Michael Walsh, "California's Low Emission Vehicle Program Compared to U.S. EPA's Tier 2 Program," 20 January 2000, 13.
[4] *Association of International Automobile Manufacturers et al. v. Commissioner, Massachusetts Department of Environmental Protection*, 208 F.3d 1 (1st Cir., 2000).
[5] The Clean Air Act requires that automakers be given two model years' lead time for compliance by states adopting California emission standards.
[6] California Environmental Protection Agency, Air Resources Board, "Zero Emission Vehicle Program Changes," Fact Sheet, 23 February 2001.
[7] In this case, "zero" evaporative emissions refers to emissions from fuel. Hydrocarbon evaporative emissions also come from other sources, including paint, adhesives, air conditioning refrigerants, vinyl, tires, etc. Source: California Air Resources Board, "California Evaporative Emission Test Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles," I.E.1(2), adopted 5 August 1999.
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[9] ibid
[10] Massachusetts Department of Environmental Protection, Bureau of Waste Management, Division of Consumer and Transportation Programs, "Background Document and Technical Support for: Public Hearings on the Proposed Amendments to the State Implementation Plan for Ozone; and Public Hearing and Findings Under the Massachusetts Low Emission Vehicle Statute," October 1999.
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