

Ready to Roll

The Benefits of Today's
Advanced-Technology Vehicles
for Maryland

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Table of Contents

Executive Summary	5
Introduction	8
Why We Need Advanced-Technology Vehicles	10
What Is an Advanced-Technology Vehicle?	10
Air Quality	11
Global Warming	13
Energy Security	14
The Need for Immediate Action	15
Advanced-Technology Vehicles Available Today	16
Hybrid-Electric Vehicles	16
Natural Gas Vehicles	19
Clean Conventional Vehicles	22
Battery-Electric Vehicles	25
Advanced-Technology Vehicles Available Tomorrow	29
Plug-In Hybrids	29
Hydrogen Fuel-Cell Vehicles	30
Getting Advanced-Technology Vehicles on the Road: The LEV Program	33
History	33
How It Works	34
Benefits	37
Cost	38
Policy Recommendations	42
Glossary of Abbreviations	43
Notes	44

Executive Summary

Despite tighter automobile emission standards over the last three decades, Maryland continues to face significant automobile-related air pollution problems. Increasing the use of advanced-technology vehicles—those that use cleaner, alternative fuels or new technological advances to achieve dramatically improved environmental performance—could alleviate the state’s air pollution problems while reducing Maryland’s contribution to global warming and enhancing the state’s energy security.

Policies such as the Low-Emission Vehicle II (LEV II) emission standards that have been adopted or are in the process of being adopted by New Jersey, New York, Massachusetts and five other states can help bring increased numbers of advanced-technology vehicles to Maryland.

The inefficient use of petroleum to power the state’s transportation system poses serious threats to Maryland’s environment and economy.

- Concentrations of air toxics such as benzene, formaldehyde, 1,3-butadiene

and acetaldehyde exceed federal health standards and raise Maryland residents’ cancer risk.

- During the summer of 2002, air pollution monitors in Maryland registered 275 instances on 40 separate days when smog levels exceeded EPA health standards for smog. In the Baltimore area, light-duty vehicles such as cars, pick-up trucks, minivans and sport utility vehicles (SUVs) are responsible for almost one-third of all emissions of nitrogen oxides and volatile organic compounds (VOCs) to the air. Nitrogen oxides and VOCs are the chemical components of smog.
- Mobile sources, such as cars and light trucks, are responsible for about 30 percent of Maryland’s emissions of greenhouse gases, which cause global warming. Global warming poses severe potential threats to coastal and forest ecosystems and public health in the state. With 3,100 miles of tidally influenced coastline, Maryland is particularly vulnerable to any rise in sea level.

- Maryland's overreliance on petroleum for transportation leaves the state susceptible to rising prices, price spikes and supply disruptions. These problems will become more severe over the next several decades.

Advanced-technology vehicles can alleviate many of these problems.

- Advanced-technology vehicles can significantly reduce emissions of air toxics and smog-forming pollutants from Maryland cars and light trucks. The current generation of hybrid-electric vehicles—such as the Toyota Prius and the Honda Civic—are approximately 90 percent cleaner than the average vehicle on sale in Maryland today. Clean conventional vehicles with state-of-the-art emission-reduction technology are now being manufactured that attain similar air toxics and VOC pollution reductions.
- Advanced-technology vehicles can also reduce Maryland's emissions of greenhouse gases, which cause global warming. Vehicles that take advantage of the benefits of hybrid-electric technology can produce about half as much global warming-inducing carbon dioxide per mile as conventional vehicles.
- Advanced-technology vehicles can enhance Maryland's energy security by improving fuel efficiency or using alternative fuels such as natural gas, electric power or hydrogen.

Several types of advanced-technology vehicles are "ready to roll," yet availability of these vehicles in Maryland is limited.

- **Hybrid-electric vehicles:** About 43,000 hybrid-electric vehicles were sold in the U.S. in 2003, an increase of 26 percent over the previous year. As

many as 60 percent of potential vehicle buyers surveyed stated that they would consider buying a hybrid, yet only a few models of hybrid vehicles are currently available to Maryland consumers.

- **Natural gas vehicles:** More than 130,000 natural gas vehicles are currently on American roads in a variety of styles and configurations. Yet, only one automaker is thus far offering them for sale to the general public.
- **Clean conventional vehicles:** Twelve automakers now manufacture vehicles that meet California's rigorous partial Zero Emission Vehicle (PZEV) emission standards. However, most of these vehicles have been made available only to consumers in states that have adopted LEV II.
- **Battery-electric vehicles:** Automakers have sold more than 10,000 zero-emission battery-electric vehicles to consumers in California and other states over the last decade. However, no major automaker currently sells battery-electric vehicles to consumers.
- Other types of vehicles—such as "plug-in" hybrids and hydrogen fuel-cell vehicles—also show the potential for significant environmental benefits, but will require further research and development before they become commercially feasible.

Adopting LEV II would put tens of thousands of advanced-technology vehicles on Maryland's roads by the end of the decade, at minimal additional cost to automakers and potential net benefit to consumers.

- LEV II would require automakers to sell approximately 89,000 hybrid-

electric vehicles and 477,000 clean conventional vehicles in Maryland between 2007 and 2010, with the numbers increasing over time.

- Installing the technology to meet these targets would cost automakers approximately \$34.4 million in 2007. The incremental cost of the program in 2007 represents 0.004 percent of gross sales at the six major manufacturers. These costs will be offset by financial benefits from technology improvements that can be exported to other vehicle lines, assistance in complying with other regulatory standards, and consumers' willingness to pay more for some LEV II-compliant vehicles.
- Consumers are unlikely to be negatively affected by LEV II. Most automakers have chosen not to pass on the direct additional cost of conforming with PZEV emission standards. Should the cost of hybrid-electric vehicles decrease (as is anticipated) and gas prices continue to rise, many consumers will see a net financial benefit from purchasing hybrid-electric vehicles.

- Automakers have already invested in research and production facilities necessary to comply with standards in other states, which represent 26 percent of the national car market.

Adoption of LEV II is essential to getting clean, advanced-technology vehicles onto Maryland's roads.

- LEV II would ensure a consistent supply of clean vehicles for Maryland consumers, create economies of scale necessary to allow the construction of alternative-fuel infrastructure, set high standards for vehicle technology, and help guide the development of even cleaner automotive technologies in the years to come.
- The goals of LEV II are attainable, and achieving them would be beneficial to Maryland. To ensure successful implementation of the program, the state should offer incentives for the purchase of zero-emission and near zero-emission vehicles, take a leadership role in educating the public about clean cars, and work to secure resources to support those efforts.

Introduction

A revolution has taken place in automotive technology over the last decade.

Hybrid-electric vehicles—virtually unknown ten years ago—have begun to make their way onto Maryland’s highways, offering dramatically increased gasoline mileage and lower emissions of toxics and smog-forming pollutants. Natural gas and other alternative-fuel vehicles have become commonplace in government and private fleets. Conventional gasoline vehicles are now being made that are virtually free of smog-forming and toxic emissions (though not global warming emissions)—a far cry from ten years ago.

Small numbers of hydrogen-powered fuel-cell vehicles—once an engineering fantasy—are now on the roads in demonstration projects, with more to come soon. And new vehicle types—such as “plug-in” hybrids that fuse the benefits of hybrid-electric and battery-electric vehicles—are on the drawing board. Much of this never would have happened without more stringent emissions standards.

The promise of a new generation of cleaner, more environmentally benign

cars has never been brighter. Yet, the vast majority of vehicles sold in Maryland today do not incorporate the latest in advanced technology. Even worse, many of the most promising advanced-technology vehicles cannot be easily purchased by Maryland residents.

Across the nation, a similar story has unfolded, with the advances made in the laboratory largely failing to make their way to the street. In fact, nationwide, the average fuel economy of light-duty cars and trucks is nearly the same as it was two decades ago.¹ Air toxics—caused in part by motor vehicles—continue to threaten the health of hundreds of millions of Americans. And the nation remains vulnerable to price spikes due to the inefficient use of petroleum as a transportation fuel.

Getting advanced-technology vehicles onto Maryland’s roads will require more than just financial incentives. For years, buyers of alternative-fuel vehicles have been eligible for federal and state tax breaks and other benefits. Yet, for the most part, the vehicles have simply not been made available to the general public. Even hybrid-electric vehicles—

now seven years removed from their successful introduction in Japan—are still only available in a limited variety of models.

There is a way to get large numbers of advanced-technology vehicles onto the state's roads in the near future. In 1990, the state of California enacted Low-Emission Vehicle (LEV) requirements. Much amended since its initial incarnation, the LEV program requires each of the major automakers to sell significant numbers of hybrid-electric, clean conventional, and other advanced-technology cars in the near future. And the program has the potential to also spur the development of the next generation of cleaner

cars: battery-electric, plug-in hybrid, and hydrogen fuel-cell cars.

Seeing the value of the LEV II program's unique approach, a number of states—New Jersey, New York, Massachusetts, Connecticut, Vermont, Rhode Island, and Maine—have moved to adopt the program for themselves. Other states are now considering whether to follow suit.

Residents of those states will soon get to see the clean car revolution take place on their roads—with accompanying benefits in air quality, energy security, and the reduction of greenhouse gas emissions to the atmosphere.

Maryland cannot afford to let this revolution pass us by.

Why We Need Advanced-Technology Vehicles

The internal combustion engine has proven to be one of the defining technologies of the 20th century, providing mobility to millions at relatively low cost. However, our inefficient use of fossil fuels—particularly for transportation—has also led to a variety of negative impacts, including air pollution, the build-up of greenhouse gases in the atmosphere, and economic harm from periodic price spikes and supply disruptions. While pollution-control mechanisms for cars and trucks have reduced some of these impacts, others are inherent in the process of burning fossil fuels in internal combustion engines. The development and widespread use of a new generation of advanced-technology vehicles could help to address many of these problems.

What Is an Advanced-Technology Vehicle?

An advanced-technology vehicle can be defined as one that uses cleaner, alternative fuels or new technological advances to achieve

dramatically improved environmental results.

While there are many types of automotive technologies and alternative fuels that are environmentally beneficial, this report will focus on several technologies with clear environmental benefits that are either available to the public now, or could be available in the near future.

- **Hybrid-electric vehicles** – Hybrid-electric vehicles, such as the Toyota Prius, Ford Escape and Honda Insight, use an on-board electric motor to assist in the propulsion of the vehicle, resulting in significantly greater fuel economy than conventional vehicles. Unlike battery-electric vehicles, hybrid-electric vehicles do not need to be recharged through a connection to the electric grid.
- **Clean conventional vehicles** – In recent years, automakers have begun to introduce conventional, gasoline-powered vehicles that are virtually free of toxic and smog-forming emissions. Other technological

advances allow the production of vehicles with improved fuel economy, potentially reducing the emission of greenhouse gases to the atmosphere.

- **Dedicated natural gas vehicles** – Two types of natural gas are currently used to power vehicles, liquefied natural gas (LNG) and compressed natural gas (CNG), with CNG vehicles far more common. “Dedicated” alternative-fuel vehicles differ from “bi-fuel” or “flexible fuel” vehicles in that they can be operated only on the alternative fuel, not gasoline.
- **Battery-electric vehicles** – Battery-electric vehicles rely on an on-board electric motor as the sole means of propelling the vehicle. The vehicle’s battery is recharged through a connection to the electric grid.
- **“Plug-in” hybrids** – “Plug-in” hybrids are hybrid-electric vehicles that can be operated for short distances on battery power alone. The on-board battery must be recharged through connection to the electric grid, although it also stores power otherwise lost in braking in the same manner as other hybrid vehicles. When the battery is discharged, the gasoline-powered internal combustion engine takes over propulsion of the vehicle.
- **Fuel-cell vehicles** – Fuel-cell vehicles are electric vehicles that generate their power through a chemical reaction involving hydrogen. The hydrogen may be reformed from natural gas or other fossil fuels, or created using electricity from fossil, nuclear or renewable sources. However, technological and cost restraints mean that fuel cell vehicles will not be available to consumers in the near future.

A more detailed review of these technologies forms the bulk of this report. But why are these new technologies necessary?

Air Quality

Advanced-technology vehicles have the capacity to address several of the problems posed by conventional vehicles, including their impact on air quality.

Toxic air contaminants pose severe threats to the health of thousands of Maryland residents. Further, the entire state of Maryland fails to meet federal health standards for ozone smog.² With many Maryland residents driving increasing distances in their cars, the threat posed by automotive air pollutants to public health is likely to increase.

Air Toxics

Airborne toxic chemicals pose a significant health threat to Maryland residents. In 1996, concentrations of air toxics and diesel soot in Maryland’s air were sufficient to pose a statewide average cancer risk of one new case for every 1,812 residents—well above the EPA’s one-in-a-million cancer risk benchmark. Residents of every Maryland county were exposed to levels of benzene, formaldehyde, 1,3-butadiene and acetaldehyde that exceeded the one-in-a-million cancer risk benchmark. In each case, pollution from mobile sources (including cars, trucks and off-road equipment) accounted for significant portions of the added cancer risk.³ (See Table 1.)

Smog

During the summer of 2002, air pollution monitors in Maryland registered 275 instances on 40 separate days in which air quality failed to meet EPA health standards for ground-level ozone, better known as smog. This is approximately 29

Table 1: Health Risk from Air Toxics Exposure in Maryland⁴

	Estimated Average Human Exposure Concentration (micrograms per cubic meter)	Factor by which Estimated Exposure Exceeds Health-Protective Threshold for Cancer	Percent of Added Cancer Risk from Mobile Sources	Maryland's Rank Nationally
Acetaldehyde	0.82	2	91%	6
Benzene	1.77	14	74%	3
1,3-Butadiene	0.08	2	96%	5
Formaldehyde	1.19	15	80%	5

percent more violations than were registered in 2001.⁵

Smog is formed as a result of a chemical reaction involving sunlight, nitrogen oxides (NO_x), and volatile organic compounds (VOCs). Exposure to smog has been linked to increased hospital emergency room visits, asthma attacks, and perhaps to the onset of asthma itself.⁶

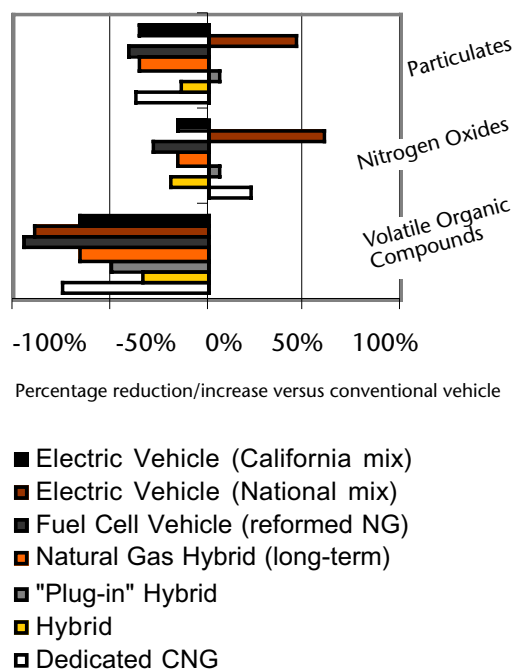
On-road motor vehicles are major contributors to the smog problem. In the Baltimore area, cars, pick-up trucks, vans and SUVs—otherwise known as light-duty vehicles—are responsible for nearly one-third of all NO_x and VOCs emissions.⁷

Air Toxics and Smog Emissions From Different Technologies

Researchers with the Argonne National Laboratories have estimated the per-mile emission levels of a variety of existing and prospective automotive technologies over the entire fuel cycle, from “well to wheels.”⁸ Their analysis shows that the use of advanced technologies can significantly reduce air emissions versus conventional, internal combustion engine vehicles operating on gasoline.

Fuel-cell and hybrid vehicles have significantly reduced per-mile fuel-cycle emissions of nitrogen oxides and volatile

Figure 1: Per-Mile Emissions of Advanced-Technology Vehicles⁹⁹



organic compounds versus conventional gasoline-powered cars. The benefits of electric vehicles and “plug-in” hybrids, however, depend on the cleanliness of the fuel “mix” used to generate the electric power they consume. The data from Argonne National Laboratories illustrates this by showing the difference in emissions from cars drawing from the

national electricity mix versus California's electricity mix that uses less coal. (See Figure 1.) The environmental impacts of hydrogen also depend a great deal on the energy sources used to create it. Hydrogen created from fossil fuel-based electricity can produce significant amounts of air pollution.

It is also important to note that two of the technologies listed above—natural gas hybrid vehicles and fuel-cell vehicles—are less developed and thus their environmental benefits are more speculative. However, a fuel-cell vehicle that runs on hydrogen derived from electrolysis of water powered by renewable fuels will be virtually emission-free.

Global Warming

Carbon dioxide and other greenhouse gas pollutants pose serious threats to the health of Maryland's residents. Over the last century, the average annual temperature in College Park has increased by 2.4° F and precipitation has increased by 10 percent in some parts of the state. Globally, average temperatures increased during the 20th century by about 1° F. In the context of the past 1,000 years, this amount of temperature change is unprecedented.¹⁰ Further, these recent warming trends cannot be explained by natural variables—such as solar cycles or volcanic eruptions—but they do correspond to

Evaluating Advanced-Technology Vehicles: The LEV II Standard

In 1990, California adopted the Low-Emission Vehicle (LEV) program, which set aggressive emission standards for automobiles. A key facet of the program required automakers to sell increasing numbers of vehicles with no tailpipe emissions. The LEV program has subsequently been modified to allow credit for vehicles with extremely low emissions, and has been adopted by six other states.

A more detailed discussion of LEV II follows later in this report. However, the program includes a series of standards that are useful in evaluating the environmental performance of advanced-technology vehicles.

Automobiles meeting super-low emission vehicle (SULEV) standards under LEV II release about 90 percent less smog-forming pollution than the average vehicle sold today.

Vehicles that receive partial Zero-Emission Vehicle (PZEV) credit under LEV II must achieve SULEV emission standards, emit “zero” evaporative hydrocarbons, and come with an extended exhaust-system warranty.

Advanced-technology PZEVs (AT-PZEVs) must meet all the standards of ordinary PZEVs, and must either include advanced technologies such as hybrid-electric drive, or be operated on inherently cleaner alternative fuels such as natural gas.

Zero-emission vehicles (ZEVs) are the “gold standard” for automobile environmental performance. ZEVs emit no harmful pollutants directly to the environment (although off-site generation of power or reformation of hydrogen to fuel ZEVs often creates pollution).

models of climate change based on human influence.¹¹

Should the concentration of greenhouse gases continue to increase over the next century, Maryland could see a further 9° F increase in average temperature and a 10 to 40 percent increase in precipitation.¹²

These changes will have a significant effect on the environment and our way of life. Potential impacts include increased heat-related deaths, the spread of tropical diseases, coastal flooding, beach erosion, loss of wetlands, reduced crop yields, and alteration of forest and other ecosystems that would shift the range of many plants and animals.¹³ With 3,100 miles of tidally influenced coastline, Maryland is particularly vulnerable to any rise in sea level.¹⁴ In addition, rising temperatures are likely to lead to longer and more severe smog seasons (given current levels of smog-forming gases), further placing public health at risk.

In 1990, Maryland released approximately 18.9 million metric tons of carbon equivalent (MMTCE) of greenhouse gases to the atmosphere. Of that amount, 5.9 MMTCE—or approximately 31 percent—came from mobile sources such as cars and trucks.¹⁵

Global Warming Emissions From Different Technologies

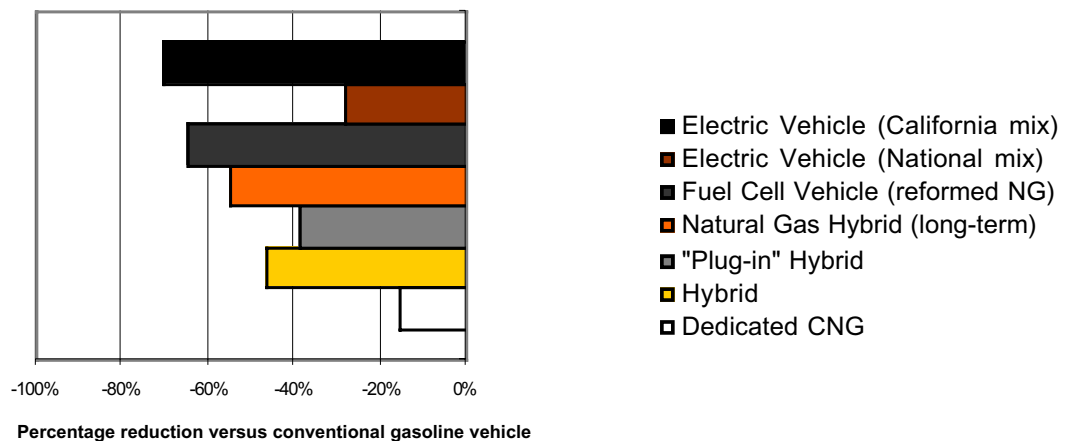
No technology akin to the catalytic converter, which filters smog-forming particles from vehicle exhaust, currently exists to directly control carbon dioxide emissions from motor vehicles. As a result, carbon dioxide emissions from vehicles are dependent on a) the carbon content of the fuel that powers the vehicle and b) the vehicle's efficiency in using the fuel. (Vehicles also emit other greenhouse gases—such as fluorocarbons from air conditioning systems—that are not directly dependent on fuel economy or fuel choice.)

Because many advanced-technology vehicles rely on cleaner fuels or boast significant increases in efficiency, their use can lead to significant reductions in carbon dioxide emissions versus conventional vehicles, as shown in Figure 2.

Energy Security

The nation's reliance on fossil fuels—particularly petroleum—to power our vehicles leaves us vulnerable to rising prices, price spikes, and supply disruptions, such as those that occurred during the oil embargoes of the 1970s.

Figure 2: Per-Mile Carbon Dioxide Emissions of Advanced-Technology Vehicles¹⁶



Even without a dramatic event such as an oil embargo, price and supply problems are likely to occur as worldwide demand rises and readily accessible sources of oil are exhausted. Recent increases in oil prices to 21-year highs are due to economic growth in developing countries, instability in the Middle East, and supply limits in many oil-producing countries.¹⁷ These forces are part of the long-term trend influencing oil prices.

The U.S. Energy Information Administration (EIA) projects that, at current rates of growth in oil consumption, oil production worldwide will peak in about 2037, leading to shortages and dramatically higher prices.¹⁸ Other analysts have criticized the EIA's assumptions as far too optimistic and suggest that peak oil production could come as soon as the end of the next decade—or about the time many of today's new cars, trucks and SUVs reach the end of their useful lives.¹⁹

Energy Consumption of Different Technologies

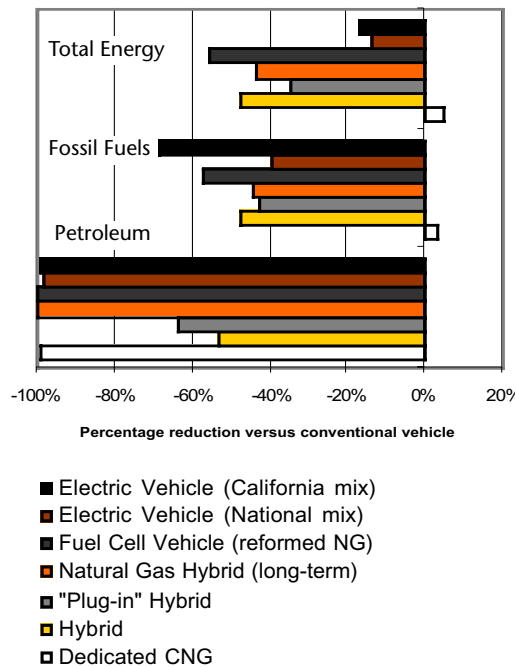
By switching to alternative fuels, or by improving vehicular fuel efficiency, advanced-technology vehicles can reduce Maryland's dependence on petroleum and fossil fuels. (See Figure 3.)

However, while most of the advanced-technology vehicles considered in this report could reduce Maryland's consumption of petroleum, fuel supply could pose a problem for some types of advanced vehicles, particularly those that operate on natural gas.

The Need for Immediate Action

Maryland residents drove 28 percent more miles on the state's highways in

Figure 3: Per-Mile Energy Use of Advanced-Technology Vehicles²⁰



2002 than they did in 1992.²¹ This trend is like to continue and as a result, Maryland will continue to face major negative public health, environmental and economic consequences of automobile air pollution.

As shown above, a variety of advanced-technology vehicles can provide significant benefits to Maryland. But to take full advantage of these benefits, the state must act to get more advanced-technology vehicles on the road as soon as possible. The vehicles in showrooms today will continue to travel the state's roads for the next 12 to 15 years. Ensuring that a significant portion of those vehicles use clean technologies could lead to environmental benefits well into the future, while paving the way for a transition to even cleaner vehicles in the decades to come.

Many types of cleaner automobiles are either available now or are technologically feasible. A more in-depth review of these technologies follows.

Advanced-Technology Vehicles Available Today

Hybrid-Electric Vehicles

The hybrid-electric vehicle is a relative newcomer to Maryland's roads, but the concept of a gasoline-electric vehicle has been around for about a century. After an initial burst of interest at the start of the 20th century, hybrid vehicle designs remained virtually unexplored until the oil crisis of the 1970s. When that crisis abated, however, hybrids again were put on the research back burner.

By the 1990s, the development of advanced nickel-metal hydride batteries (driven by research conducted for battery-electric vehicles) and other automotive technologies led to renewed interest in hybrids. Toyota was the first major automaker to manufacture a hybrid car and introduced the Prius in Japan in 1997. Three years later, Toyota introduced the Prius to the United States while Honda began sales of its two-seat Insight model. In 2002, Honda introduced the Civic hybrid—the first application of hybrid technology within an existing vehicle line. Ford soon will be releasing a hybrid version of its Escape SUV. Vehicle fleet operators already can buy a mild hybrid



A 2004 model year Toyota Prius

version of General Motors' Silverado pickup, and that vehicle will soon be available to all consumers.

The Toyota Prius (above) was one of the first hybrid-electric vehicles introduced to the United States. By 2005, Toyota expects to sell approximately 300,000 hybrids per year worldwide.

Vehicle Characteristics

Not all vehicles labeled "hybrids" by their manufacturers are alike. In fact, the term "hybrid" itself refers to a package of

technologies, not all of which are included in every vehicle.

A “full” hybrid vehicle—such as the Toyota Prius—includes four basic characteristics:

- The capability to shut off the conventional engine when the vehicle is stopped.
- The use of regenerative braking, which captures energy that would otherwise be lost when a vehicle slows down.
- Reduced engine size versus conventional vehicles.
- The capability to drive the vehicle using only electric power.²²

A “mild” hybrid, such as the Honda Civic or Insight, includes all of these characteristics except the ability to drive the vehicle using only electric power.

The technological difference between full and mild hybrids does not necessarily mean that one type of hybrid system is more beneficial for the environment than the other. In fact, the most fuel-efficient vehicle for sale in the U.S.—the Honda Insight—is a “mild” hybrid. Of greater importance is the percentage of a vehicle’s power that is derived from the electric motor.

In addition to mild and full hybrids, the Union of Concerned Scientists has defined another category—the “muscle hybrid”—for vehicles that take advantage of idle shut-off and regenerative braking technologies without downsizing the engine. In these vehicles, the hybrid system is used primarily to add power to the vehicle, not to bring about increased fuel efficiency. For example, GM describes its hybrid Silverado pick-up truck—available to fleets and soon to consumers—as a “portable generator on wheels” because of its four 110-volt outlets.²³ The environmental benefits of this type of hybrid

are minimal; the hybrid system in the Silverado, for example, boosts fuel economy by only 10 to 12 percent.²⁴

A fifth potential characteristic of hybrids—the ability to travel extended distances in electric-only mode—will be discussed in the section on “plug-in” hybrids later in this report.

The first generation of hybrid-electric vehicles has demonstrated clear environmental advantages over conventional vehicles. The three model-year 2004 hybrid-electric vehicles each achieved EPA-rated fuel economy of greater than 45 miles per gallon (MPG)—nearly 10 MPG greater than the nearest gasoline-powered vehicle.²⁵ In addition, the 2004 models of all three vehicles are certified as super-low emission vehicles (SULEVs) in California, meaning that their emissions are 90 percent cleaner than the average 2004 model year car.²⁶ Ford says that its hybrid Escape SUV will meet AT-PZEV standards when the 2005 model year vehicle is released.²⁷ AT-PZEVs meet SULEV emissions standards, have “zero” evaporative emissions, and offer an extended warranty.

Manufacturing Experience

As noted above, Toyota was the first major auto company to introduce a hybrid to the consumer market in 1997 in Japan. In the years since, Toyota and Honda have expanded the availability of their hybrid vehicles in the United States. (See Table 2.)

While hybrids still represent only a

Table 2: Model Year 2004 Hybrid-Electric Vehicles Available to the General Public

Manufacturer	Model	Type
Toyota	Prius	Full Hybrid
Honda	Civic	Mild Hybrid
Honda	Insight	Mild Hybrid

small percentage of new vehicle sales in the U.S., that could change in the years to come. Toyota, for example, anticipates manufacturing 300,000 hybrids per year by 2005.²⁸ Over the next 10 years, more than one million hybrid vehicles may be sold in the U.S.²⁹

Four years after Japanese automakers introduced hybrids to the U.S., America's "Big Three" automakers still have yet to sell their first hybrid to the general public—although they will very soon. American automakers are preparing to introduce their first consumer-market hybrid models within the next year.

General Motors – GM currently offers "muscle hybrid" versions of its Sierra and Silverado trucks to fleet customers and intends to make them available to retail customers in late 2004.³⁰ In 2005, GM plans to introduce a hybrid version of its Saturn VUE SUV that will get approximately 12 to 15 percent better gas mileage.³¹ The company has announced that it will include a variety of hybrid technologies in several other vehicles between 2005 and 2007.³²

Ford – Ford plans to market a full hybrid version of its Escape SUV to the general public in late summer 2004. Ford projects the vehicle will receive an EPA fuel rating for in-city fuel economy of 35 MPG—an increase of more than 40 percent versus current Escape models.³³ The Escape would be the first SUV to take substantial advantage of hybrid technology. Ford bought several patents from Toyota to incorporate Toyota's hybrid technology into the Escape.³⁴

DaimlerChrysler – DaimlerChrysler is expected to introduce a hybrid-electric version of its Dodge Ram pickup truck in 2005.³⁵ DaimlerChrysler is also reported to be in discussions with Toyota about purchasing the company's hybrid system for use in a future hybrid-electric vehicle—a strategy similar to that being employed by Nissan.³⁶

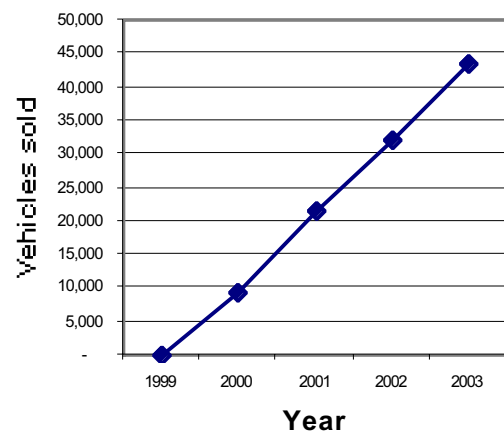
Consumer Acceptance

Hybrid-electric vehicles have met with a warm consumer response in the U.S., despite their somewhat higher initial cost and the limited number of models available. Many attribute the success of hybrids to their similarity to traditional gasoline-powered vehicles. Hybrids are fueled the same way, achieve greater range, and are generally similar in performance to conventional vehicles.

Sales of hybrid vehicles have increased steadily since their introduction to the domestic market in December 1999. About 43,000 hybrids were sold in the U.S. in 2003, an increase of 26 percent from the previous year.³⁷ (See Figure 4.) Since 2000, hybrid sales have grown at an average annual rate of 89 percent.³⁸ As oil prices rise, demand for hybrids has increased further. Toyota and Honda reported 30 percent increases in sales of hybrids in the weeks leading up to U.S. military intervention in Iraq in March 2003, and this year Toyota reports that sales of the Prius have doubled compared to 2003.³⁹

The market potential of hybrids has only begun to be tapped. A recent J.D. Power and Associates report found that

Figure 4: Hybrid-Electric Vehicle Sales, U.S.⁴⁰



60 percent of new vehicle buyers would consider buying a hybrid-electric vehicle. Nearly one-third of those said they would buy a hybrid even if the added cost of the vehicle were not fully offset by fuel savings.⁴¹ Yet, in part due to the failure of major American automakers to bring a hybrid to market, the market is failing to satisfy consumers' desire for hybrid-electric vehicles. Consumers who want to purchase the Toyota Prius face a six-month long waiting list, if they can even get on the list in the first place.⁴² Drivers who want to buy a Honda Insight or Civic hybrid also face a delay, although it is shorter.⁴³ More than 34,000 people have signed up for a newsletter about the Ford Escape hybrid, but Ford plans to build only 20,000 vehicles in the first year.⁴⁴

Future Prospects

While existing hybrid-electric vehicles have demonstrated significant gains in fuel economy and emission reductions, even greater improvements are possible in the future. One 2003 study projected that the application of advanced technologies—such as continuously variable transmissions and advanced batteries—and more advanced hybrid systems could lead to a new-vehicle fleet average fuel economy of 50 to 60 MPG by 2020.⁴⁵

Achieving the full potential of hybrid electrics will not happen without effort. Public policies must be enacted to ensure not only that hybrids are made available to consumers, but also that those hybrids achieve significant energy efficiency and emissions benefits versus conventional vehicles.

Natural Gas Vehicles

Vehicles powered by natural gas have distinct environmental advantages over those powered by gasoline. However, limitations in supplies of natural gas and volatile prices

make natural gas unsuitable as a long-term or widescale replacement for gasoline-powered vehicles. In the short term, limited use of natural gas vehicles can produce interim environmental benefits.



Photo credit: DOE/NREL

Honda's natural-gas powered Civic GX is the first such car to be sold to the general public in the U.S.

Vehicle Characteristics

Natural gas can be supplied to vehicles in one of two forms: compressed natural gas (CNG) or liquefied natural gas (LNG). CNG vehicles are much more common, but because of the low energy density of compressed gas, the vehicles must carry bulky tanks on board the vehicle. LNG possesses greater energy density, but requires a complex storage system to keep the fuel cold enough to remain in liquid form.

Natural gas vehicles use an internal combustion engine similar to that in conventional gasoline vehicles. Vehicle performance is comparable to that of conventional vehicles as well, with the exception of range, which tends to be somewhat shorter due to the low energy density of the fuel.

Among the benefits of CNG vehicles are fuel prices that are generally lower than gasoline, albeit subject to significant regional disparities and periodic price

swings. As of March 2004, CNG prices per gasoline-gallon-equivalent ranged from \$1.07 to \$1.59 compared to gasoline prices of \$1.61 to \$2.03 per gallon (lower than the current range of gasoline prices).⁴⁶ The initial cost of a CNG vehicle is comparable to or slightly higher than that of a hybrid-electric vehicle.

CNG vehicles have the potential for extremely low emissions. Three models of trucks—all made by Ford—are certified as SULEVs by the state of California, while the Honda Civic GX has been certified to receive advanced technology partial Zero-Emission Vehicle (PZEV) credit as a result of its low tailpipe and evaporative emissions and emission-system warranty.⁴⁷

The biggest challenge to the success of natural gas vehicles has been the lack of available refueling facilities. As of May 2004, there were only 1,035 refueling sites for CNG vehicles nationwide, of which 20 were in Maryland, and 62 sites for LNG vehicles, with none in Maryland.⁴⁸ Of the 20 CNG fueling stations in the state, only 12 are open to the public, and the use of many of those public stations is subject to restrictions. 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.⁴⁹ The high costs of CNG refueling stations have generally limited construction to firms with CNG fleets that can refuel centrally and to natural gas suppliers.

However, the spread of home refueling systems could make CNG vehicles more attractive in the years to come. In 2002, FuelMaker Corp.—in partnership with American Honda—unveiled a prototype of the first home CNG-vehicle fueling system, which it projected would be available for sale in late 2003 but is not yet on the market.⁵⁰ The cost of the appliance—which is about the size of a pay-phone booth, takes its natural gas from a home’s gas line, and can refuel a vehicle overnight—is anticipated to be between \$1,000 and \$1,500.⁵¹

Another major drawback of CNG vehicles is the size of the fuel tanks. Evaluators with the U.S. Department of Energy compared the natural gas-powered Honda Civic GX with a conventional Civic and found the CNG vehicle to be equal or superior to the gasoline vehicle in every category but one: trunk space. The CNG Civic was rated “poor” for trunk space—due to the limited room allowed by the CNG storage tank—while its conventional cousin received an “excellent” rating.⁵²

Manufacturing Experience

The number of natural gas vehicles on American roads has increased more than five-fold over the last decade. In 1992, only 23,000 CNG vehicles were on the road, compared to an estimated 133,000 in 2003.⁵³ (See Figure 5.) In addition, there are an estimated 3,000 LNG vehicles in use today, compared to just 300 in 1993.

Figure 5: Compressed Natural Gas Vehicles in Use, U.S.

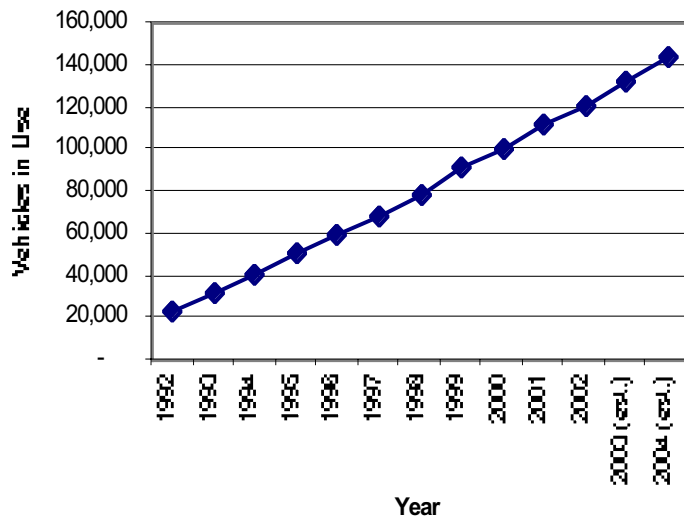


Table 3: Model Year 2003 Compressed Natural Gas Vehicles⁵⁴

Manufacturer	Model	Type	CA Emission Rating
Honda	Civic GX	Car	PZEV
Dodge	Ram Van 2500	LDT	SULEV
Dodge	Ram Van 3500	LDT	SULEV
Dodge	Ram Wagon 2500	LDT	SULEV
Dodge	Ram Wagon 3500	LDT	SULEV
Ford	E-250	LDT	SULEV
Ford	E-350	LDT	SULEV
Ford	F-150	LDT	SULEV
Chevrolet	S-10	LDT	ULEV
Chevrolet	Blazer	LDT	ULEV
GMC	Sonoma	LDT	ULEV
GMC	Jimmy	LDT	ULEV

LDT = Light-duty truck. SULEV = Super low-emission vehicle. ULEV = Ultra low-emission vehicle.

Many major automakers—including Ford, DaimlerChrysler, General Motors, Honda and Toyota—manufacture CNG versions of their conventional vehicles, mostly for vehicle fleets. (See Table 3.) Only Honda, however, appears to be committed to a strategy of selling CNG vehicles to individual consumers.

Consumer Acceptance

While individual consumers have had limited experience with CNG vehicles, the vehicles have become increasingly popular with government and private fleets.

In a 1999 survey by the U.S. Department of Energy’s National Renewable Energy Laboratory, 96 percent of drivers of city government fleet CNG vehicles rated the overall performance of their vehicles as excellent or very good. Among state fleet drivers, 85 percent rated performance of their dedicated CNG vehicles as excellent or very good. More than half of all dedicated CNG vehicle drivers said that they would

recommend an alternative-fuel vehicle to others.⁵⁵

CNG vehicles could be positively received by consumers, especially for those applications that do not require maximum cargo space or driving long distances. Adoption could be greater if public refueling opportunities are expanded, or if home refueling proves workable. And CNG vehicles will continue to be a solid option for vehicle fleets and urban settings.

Future Prospects

Research to improve natural gas vehicles continues, particularly around new engine and vehicle designs that maximize performance and minimize the amount of space required for fuel storage. Other efforts focus around reducing the cost of refueling stations and improving refueling speed.

Natural gas engines can also be incorporated into hybrid-electric vehicles, resulting in vehicles with even lower emissions than the current generation of

hybrids. No natural gas hybrids, however, have yet made it to market.

But the largest and most inescapable hurdle facing natural gas vehicles is the prospect for supply disruptions and price spikes due to growing demand for natural gas by electric power plants and other sources. From 1992 to 2002, consumption of natural gas in the U.S. increased by 14 percent, and the accelerating switch to natural gas for electricity generation will likely lead to a dramatic increase in overall consumption over the next several decades.⁵⁶ The U.S. Energy Information Administration conservatively projects that natural gas consumption in the U.S. will increase by 39 percent between 2002 and 2025.⁵⁷

At the same time, U.S. proved reserves of natural gas have declined by 10 percent since 1982. The nation's reserves-to-production ratio—which gauges the length of time it would take to consume all proven reserves at current rates of production—stands now at just 9.5 years.⁵⁸

Natural gas prices have risen dramatically in recent years. In the past two years alone, wholesale prices have increased by 50 percent.⁵⁹

Even if imports of natural gas increase significantly, the long-term supply and demand situation—coupled with the traditional price instability of natural gas—suggests that converting large numbers of vehicles to natural gas is not a wise course. However, more limited deployment (such as in fleets) of natural gas vehicles can result in environmental benefits. Hybrid natural gas vehicles, while more costly, could provide even greater benefits.

Clean Conventional Vehicles

Increasingly tight emission standards at the federal level and in California have driven significant reductions in emissions

of air toxics, smog-forming chemicals, and other harmful pollutants from motor vehicles over the past three decades. At the same time, however, the number of miles driven on American roads has increased dramatically, leading to continuing pollution problems.

Now, automakers are demonstrating their ability to make conventional, gasoline-powered vehicles that release virtually no air toxics and smog-forming chemicals to the air. Other technological improvements—such as the use of advanced engines, transmissions, and materials—could also bring about dramatic improvements in fuel efficiency versus today's vehicles—reducing greenhouse gas emissions and improving Maryland's energy security.

Vehicle Characteristics

Achieving California's partial Zero Emission Vehicle (PZEV) credit standards is the ultimate test of cleanliness for conventional gasoline-powered vehicles. To earn PZEV credit, a vehicle must achieve SULEV emission standards (a 90 percent reduction in emissions versus today's average vehicles), produce virtually no evaporative emissions of hydrocarbons, and have its emission control system under warranty for 150,000 miles.

Among the technologies that are being used to achieve these standards are:

- **Exhaust gas recirculation** to reduce emissions of smog-forming nitrogen oxides.
- **Oxygen sensors** that allow adjustments in the air/fuel mix in a vehicle's cylinders in order to maximize the efficiency of combustion and ensure proper function of the catalytic converter.
- **Faster-heating catalytic converters** to avoid emissions that take place while a car is heating up.

- **Improved computerized control of the engine start-up sequence** to reduce “cold start” emissions (current emission-control systems are far less effective when cold).⁶⁰
- **“Smog-eating” coatings** on radiators that convert ground-level ozone in ambient air into oxygen.⁶¹
- **Modified fuel tanks and lines** to control evaporative emissions.

In addition to implementing such technologies, automakers must stand by their durability and place the emission systems under warranty for 150,000 miles. Doing so commits automakers to dealing with a fundamental problem experienced by earlier generations of vehicles: degradation of the emission control system over time.

Reduced emissions of harmful pollutants are not the only potential benefits of applying advanced technology to conventional vehicles. A host of technologies exist that could dramatically improve the fuel efficiency of today’s vehicle fleets.

A 2001 analysis by the American Council for an Energy-Efficient Economy (ACEEE) found that improvements in automotive technology possible within the 2010-2015 timeframe could result in a 51 percent increase in average fuel economy over the entire new-car fleet at an average cost increase of only 5.8 percent—much of which would be recouped over the lifetime of the vehicle in reduced fuel costs.⁶²

Other analysts also note the potential for significant improvements in vehicle fuel economy. A 2002 National Research Council report found that automakers could cost-effectively boost the fuel economy of their fleets by 12 to 42 percent, with the greatest potential increases coming in the fuel economy of light trucks. In other words, the increase in price that consumers would face for these

fuel economy improvements would be more than offset by the fuel savings they would incur over the lifetime of the vehicle—even at a relatively low average fuel price of \$1.50 per gallon.⁶³

Among the technological advances that can improve fuel economy are:

- **Smaller, more efficient engines.**
- **Direct-injection engines** that allow greater control of the engine’s use of fuel.
- **Advanced transmissions**—such as five- and six-speed automatics and continuously variable transmissions—that allow a broader range of gear ratios.
- **Integrated starter-generators** that allow greater power and enable the vehicle to take advantage of some features of hybridization (such as idle-off).
- **Lightweight materials.**⁶⁴

Manufacturing Experience and Consumer Acceptance

To date, at least 12 automakers have manufactured conventional vehicles certified for PZEV credit in California.⁶⁵ (See Table 4.) Most vehicles that have been certified as PZEVs thus far use a combination of technologies to achieve emission reductions.

While many of the various technologies listed above have been used for several years, it has only been within the last three years that automakers have certified conventional vehicles to PZEV standards. There is little information on the degree to which PZEVs have been welcomed by consumers, though the California Air Resources Board projected sales of 2003 model year PZEVs would reach 140,000 vehicles.⁶⁷ Because some

Table 4: Certified ZEV Credit Model Year 2004 Vehicles⁶⁶

Manufacturer	Model	Certification	Fuel
BMW	325i, Ci, sport wagon	PZEV	Gasoline
DaimlerChrysler	Sebring	PZEV	Gasoline
DaimlerChrysler	Stratus	PZEV	Gasoline
Ford	Focus, wagon	PZEV	Gasoline
Honda	Accord LX, EX	PZEV	Gasoline
Honda	Civic GX	AT-PZEV	Natural Gas
Honda	Civic Hybrid	AT-PZEV	Gasoline
Hyundai	Elantra	PZEV	Gasoline
Mazda	Mazda 3	PZEV	Gasoline
Mitsubishi	Galant	PZEV	Gasoline
Nissan	Sentra	PZEV	Gasoline
Nissan	Altima 2.5	PZEV	Gasoline
Subaru	Legacy wagon	PZEV	Gasoline
Subaru	Legacy Outback	PZEV	Gasoline
Toyota	Camry	PZEV	Gasoline
Toyota	Prius	AT-PZEV	Gasoline
Volkswagen	Jetta	PZEV	Gasoline
Volvo	S60 FWD	PZEV	Gasoline
Volvo	V70 FWD	PZEV	Gasoline

PZEV technologies result in improved fuel efficiency and all vehicles are covered by a longer exhaust-system warranty, it is likely that many consumers gain increased value from their PZEV-certified vehicles.

Moreover, the emission improvements attained by vehicles meeting the PZEV standard have thus far come at limited cost. CARB has estimated that the PZEV standards themselves add only \$100 to the cost of producing a SULEV-compliant vehicle, while SULEVs cost between \$100 and \$300 more to manufacture than cars meeting current Ultra Low-Emission Vehicle (ULEV) standards.⁶⁸

To date, however, despite the small incremental cost of meeting the standards, most automakers have chosen to market PZEV-compliant vehicles only in states that have adopted LEV II, and some have limited distribution only to California.⁶⁹ Ford, however, has chosen

to sell the PZEV version of its Focus nationwide.⁷⁰

With regard to fuel economy improvements, many advanced technologies are making slow but steady progress into the marketplace. All manufacturers have succeeded in improving the efficiency of engines over the last several decades—although most of the gains have been channeled into increasing vehicle power, not reducing fuel consumption. Direct-injection engines have been used for years in diesel vehicles and automakers are beginning to experiment with their use in gasoline vehicles. Honda, Audi and Nissan have included continuously variable transmissions in some models of their vehicles.⁷¹ General Motors has introduced its Displacement on Demand technology, which allows the engine to use only half its cylinders during normal driving conditions, thus saving fuel.⁷²

Future Prospects

As the newest generation of emission-control technologies are perfected in laboratories and produced in bulk, their performance should continue to improve and their price continue to drop. But much depends on the future of government standards for vehicle emissions and especially fuel economy. While the adoption of LEV II standards in several states—coupled with the more aggressive federal emission-control strategy reflected in the national “Tier 2” standards, which are now being phased in—have helped push emission-control technology forward, no similar impetus exists for the deployment of fuel-efficiency technology to improve fuel economy in conventional vehicles.

The one program that has succeeded in improving fuel economy and reducing greenhouse gas emissions from conventional automobiles is the federal Corporate Average Fuel Economy (CAFE) program. In the decade-and-a-half following enactment of CAFE standards, the “real world” fuel economy of passenger cars nearly doubled—from 13.5 MPG in 1975 to 24.4 MPG in 1988. Similarly, light trucks experienced an increase in real-world fuel economy from 11.6 MPG in 1975 to 18.4 MPG in 1987.⁷³

However, the momentum toward more fuel efficient cars has not only stalled since the late 1980s, but it has actually reversed. The federal government has failed to increase CAFE standards for passenger cars in more than a decade, and changes in driving patterns—including higher speeds and increased urban driving—have led to a decrease in real-world fuel economy.

Further, a marketing emphasis on larger vehicles has increased the number of light trucks and SUVs on the road. When fuel economy standards were first adopted, only a small number of vehicles

sold were light trucks. Today, light trucks account for over half of vehicle sales.⁷⁴ These vehicles are subject to less stringent fuel economy standards and have thus lowered the average fuel economy of vehicles driven today. An EPA analysis of fuel economy trends found that average real-world fuel economy for light-duty vehicles sold in 2004 was lower than it was for light-duty vehicles sold in 1987.⁷⁵

The federal government recently approved a modest increase in CAFE standards for light trucks—from 20.7 MPG today to 22.2 MPG in the 2007 model year.⁷⁶ While this increase will spur the introduction of some fuel efficiency technologies over the next several years, much greater gains are technologically and economically feasible.

Maryland’s ability to improve the fuel economy of vehicles sold in the state is constrained by federal law. Maryland does, however, have the power to adopt California standards—such as LEV II—that can reduce vehicle emissions.

Battery-Electric Vehicles

Battery-electric vehicles are not a new technology. Indeed, many of the first generation of automobiles that hit American roads in the late 19th and early 20th centuries were powered by electricity. By the second decade of the 20th century, however, as gasoline became widely available at low prices and internal combustion engines were perfected, electric cars became a thing of the past.

But in recent decades, battery-electrics have again received attention for their efficiency and cleanliness.

Toyota’s RAV4-EV (shown on next page) is one of several battery-electric vehicles that have been manufactured by major automakers over the last decade.



Photo: DOE/NREL

Toyota's RAV4-EV is one of several battery-electric vehicles that have been manufactured by major auto makers over the last decade.

Vehicle Characteristics

Battery-electric vehicles (EVs) produce no emissions during vehicle operation (although they are responsible for emissions at the power plants that generate electricity to power the vehicles). They are extremely quiet and easy to operate. Operating costs tend to be low due to reduced fuel and maintenance costs. And they can be refueled overnight at home, making trips to a filling station unnecessary.

Battery-electrics also have several drawbacks. Even today's most advanced commercially available batteries store only enough energy to allow a range of 100-150 miles before refueling. Refueling itself is a slow process, usually taking several hours. And the cost of batteries—which have not yet been manufactured in sufficient quantities to achieve bulk production—has been high.

Though battery-electrics are not the best option for every need, they are practical for some uses, particularly when long range is not required and there is opportunity to charge them overnight. Neighborhood electric vehicles that are designed for in-town travel to complete errands or get to nearby destinations have become popular in select communities.

Manufacturing Experience

The production of battery-electric vehicles over the past decade has occurred in fits and starts—accelerating in the face of imminent requirements for the introduction of cleaner cars only to slow again when the requirements are eased.

In the 1990s, in response to California's enactment of the LEV program, major automakers began to develop battery-electric vehicles for sale in California. From 1998 to 2000, automakers sold more than 2,300 electric vehicles in California to fulfill the terms of a memorandum of agreement (MOA) with state officials over the implementation of the LEV program.⁷⁷

With the 2000 expiration of the MOA, 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, moved to expand the availability of its existing EV model, making the RAV4-EV—previously available only to fleets—available for individual lease in 2002.⁷⁸

A few automakers, including Ford and DaimlerChrysler, moved ahead with plans to sell “city” and “neighborhood” battery-electrics that travel at low speeds for short ranges and can be sold at lower cost. Ford's Th!nk division, for example, leased about 1,000 city electric vehicles.⁷⁹

However, the issuance of a judicial injunction against the enforcement of the ZEV requirement in 2002—and the subsequent delay in the implementation of the California LEV program until 2005—led Toyota to abandon its electric vehicle program and Ford to discontinue sales of its Th!nk city and neighborhood battery-electrics.

Nonetheless, a few battery-electrics are available for purchase or lease today,

and are quite popular. Daimler Chrysler's GEM division sells neighborhood electric vehicles (NEVs)—small cars powered by an electric motor and designed for use on short trips around town at speeds of 25 miles per hour—to consumers nationwide. Gizmo, another maker, sells NEVs with a range of 45 miles. Demand from this niche market is strong enough that prospective Gizmo buyers must wait for cars.⁸⁰ NEVs offer drivers an inexpensive, zero-emission transportation option for the short trips that make up most driving.

The experience of the past decade shows that manufacturers can produce a variety of battery-electric vehicles and that consumers will buy them.

Consumer Acceptance

Several surveys of electric vehicle owners in California show that EV drivers have been generally satisfied with their vehicles.⁸¹

Despite this consumer acceptance, automakers have long contended that no market exists for battery-electric vehicles. However, the electric vehicle experience in California—the only state in which the vehicles have been introduced in any significant numbers—suggests that the failure of automakers to supply and aggressively market battery-electric vehicles may be a greater limitation in the development of the EV market.

EV buyers in California reported having to surmount major obstacles to obtain the vehicles. Consumers reported 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.⁸² Additionally, automakers failed to offer types of vehicles that appealed to people interested in buying an EV.⁸³ And for most of the time period in which EVs were available, consumers could not

purchase them outright, but could only obtain them through leases—many of which carried restrictive terms.

A 2000 survey of California consumers conducted for the nonprofit Green Car Institute found that about one-third of California 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. Yet policies similar to those used by automakers in California reduced potential buyers' interest: 40 percent said they would purchase a gasoline vehicle if leasing were the only option for obtaining an EV.⁸⁴

Battery-electric vehicles are a viable technology for many uses. Experiments with battery-electric “station cars”—in which vehicles are leased to commuters and can be recharged at transit stations—have been undertaken in several cities. EVs have been successfully incorporated into many fleets. And most drivers who have used EVs find that the vehicles—even with their limited range—serve the vast majority of their driving needs.

Future Prospects

While previous research into battery-electric vehicles has not yet yielded a vehicle that can match the range and cost of a conventional car, progress toward those goals continues.

Three major battery technologies are used in electric vehicles, but thus far each suffers from high cost, limited driving range, and/or short life-span. And all are bulky, limiting cargo space in the vehicle.

While battery-electric vehicles do have limitations, the pace of technological advancement in battery-electric vehicle development has been astounding. Between 1990 and 2000, the practical range of EVs more than doubled (from 25-50 miles to 75-120 miles per charge), faster charging systems were developed, battery price dropped sharply, and power

increased.⁸⁵ While manufacturers are not currently producing full-function electric vehicles, they continue to pursue improved batteries and electric-drive technologies through their development of

hybrid-electric and hydrogen fuel-cell vehicles. Continued progress along this path could lead to further improvements and greater application in the years to come.

Advanced-Technology Vehicles Available Tomorrow

Plug-In Hybrids

“Plug-in” hybrid-electric vehicles combine the best attributes of gasoline-powered hybrids and electric vehicles. The vehicle’s electric motor—which is recharged through a plug-in connection to the electric grid—powers the vehicle on short trips, with the gasoline engine providing an assist on steep inclines and taking over on longer trips beyond the electric motor’s range. The result is a vehicle with the range and performance attributes of a conventional car, but with significantly reduced emissions and greater fuel economy.

Vehicle Characteristics

In comparison to conventional hybrid vehicles, plug-in hybrids require a larger battery, capable of powering the vehicle in all-electric mode for 20 to 60 miles without recharging. However, the battery is smaller than that of a traditional battery-electric vehicle, allowing the vehicle to be recharged overnight using a conventional 120-volt connection to the grid. As a result, plug-in hybrids could be

significantly less expensive and more flexible than battery-electric vehicles, due to the smaller battery and lack of need for special charging equipment.

Another benefit of plug-in hybrid design is the technology’s potential to assist the transition to hydrogen fuel-cell vehicles. In many plug-in hybrid designs, the primary source of propulsion for the vehicle is the electric motor. Because fuel-cell vehicles will also be driven by an electric motor, the development of plug-in hybrids could serve as a crucial bridge between the two technologies.

Technological Challenges

The primary challenge to the creation of plug-in hybrids is the cost of the larger batteries needed for the vehicles. Current projections suggest that plug-in hybrids will cost between \$1,500 and \$6,000 more than conventional hybrids, depending on the vehicle’s all-electric range.⁸⁶

A technical challenge—similar to that faced by battery-electric vehicles—is the prospect for degraded battery performance over time, possibly requiring costly replacement. The battery life issue in the

case of conventional hybrids has been somewhat resolved for consumers by extended warranties offered by manufacturers and the longer life-span of nickel-metal hydride batteries. But it may be of greater concern in plug-in hybrids, given the larger size of the battery and the increased importance of the battery to the performance of the vehicle.

Perhaps the largest challenge faced by plug-in hybrids, however, is the lack of interest automakers have shown in the technology. To date, no major automaker has produced a plug-in hybrid, though DaimlerChrysler is currently developing three such vehicles.⁸⁷

On the positive side, plug-in hybrids pose some distinct technological advantages. A plug-in hybrid capable of 60 miles all-electric range that is fully charged each night could save its owner as much as \$500 per year in fuel costs versus conventional vehicles (assuming fuel costs of only \$1.65 per gallon). Routine maintenance costs for such a vehicle could be as much as \$140 less per year than for a conventional car.⁸⁸ In addition, plug-in hybrids could also serve as emergency generators when the vehicle is not being driven.

Future Prospects

Absent a commitment from automakers to the technology—or regulatory requirements or financial incentives that will spark automakers' interest—plug-in hybrids do not appear as though they will be made available to consumers in the near term.

The benefits of the technology, however, combined with consumers' growing exposure to conventional hybrids, could cause automakers to take a second look at plug-in hybrids in the years ahead. For example, a recent survey found that 35 percent of mid-size car drivers studied would choose a plug-in hybrid with 20

miles all-electric range over a conventional vehicle, and 17 percent would choose a more-expensive plug-in hybrid with 60 miles all-electric range—despite the higher projected costs of the vehicles. An increase in gasoline prices would spark even greater interest.⁸⁹

In sum, plug-in hybrids represent an evolutionary technology somewhere between conventional hybrids and battery-electric vehicles. They hold the promise of added convenience, and lower fuel and maintenance costs for consumers. And while automakers are not now planning to introduce plug-in hybrids to their fleets, the basic technologies needed to manufacture the vehicles already exist—as does the refueling infrastructure.

Hydrogen Fuel-Cell Vehicles

Rapid advances in technology over the last decade have led many automakers, government officials and analysts to conclude that fuel-cell vehicles are the zero-emission vehicles of the future. How far in the future it will be before the vehicles become available is anyone's guess. But fuel-cell vehicles possess potential as a source of clean transportation.

Vehicle Characteristics

In essence, fuel-cell vehicles are electric vehicles without batteries. Electricity to drive the vehicle is derived through an electrochemical reaction involving oxygen and the car's supply of hydrogen in the presence of a catalyst such as platinum.

The hydrogen for the fuel cell can be “generated”—that is, extracted from other compounds—using one of several processes:

- **Reformation** – Hydrogen is reformed from natural gas, biomass, or other fuels by exposing the fuels

to high-temperature steam in the presence of a catalyst. The result of the process is hydrogen and carbon dioxide.

- **Electrolysis** – By exposing water to an electric current, water can be split into its constituent parts—hydrogen and oxygen. Electrolysis requires a large amount of electricity.
- **Gasification** – Using a super-heated reactor, coal or other fuels are turned into a gas, which is then exposed to steam and oxygen to create hydrogen, carbon monoxide and carbon dioxide.

Only one method of obtaining hydrogen—electrolysis—can be truly emission-free. Other methods produce significant amounts of carbon dioxide—the leading gas responsible for global warming—and other pollutants. Even electrolysis may contribute to air pollution and global warming if it is powered by electricity generated from fossil fuel-fired power plants.

When renewable energy facilities are abundant enough to be used to process vast quantities of hydrogen, electrolysis and fuel cells may become a truly sustainable transportation power source.

Technological Challenges

Hydrogen-fueled vehicles are seen as an attractive alternative to other zero-emission vehicles (such as battery-electric cars) because they hold the promise of delivering the same performance quality as traditional gasoline-powered vehicles with no harmful emissions. But several technological hurdles must be surmounted for hydrogen-powered vehicles to deliver on this promise.

The most fundamental performance issues facing hydrogen vehicles are the related problems of fuel storage and driving range. Hydrogen, though very light, has

low energy density by volume. Thus hydrogen storage poses a basic physical dilemma: vehicles must carry enough hydrogen on board to provide an acceptable driving range between fill-ups, yet must not carry storage tanks that are too large (reducing passenger or cargo room) or waste excessive amounts of energy in compression or liquefaction. In addition, they must be safe.

The Department of Energy has set a goal of developing hydrogen-powered vehicles capable of traveling 300 miles on a tank of fuel—a range similar to today’s gasoline-powered vehicles.⁹⁰ Several fuel-cell vehicle prototypes have achieved driving ranges of 200 miles or more before refueling. But there is strong skepticism among some observers as to whether the storage problem can be resolved using current technology. In a 2004 report, the National Academy of Sciences (NAS) concluded, “[T]he committee questions the use of high-pressure tanks aboard mass-marketed private passenger vehicles from cost, safety, and convenience perspectives.... The committee has a similar view of liquid hydrogen.”⁹¹

There are two potential solutions to the fuel storage problem. One is to dramatically reduce the amount of fuel that must be stored on-board the vehicle by finding ways to increase vehicle efficiency. The other, recommended by the NAS panel, is to pursue other technologies—such as storage of hydrogen in metal hydrides—that can effectively and safely store hydrogen at greater density and lower pressure.

Cost is also a major issue with regard to fuel-cell vehicles. The California Air Resources Board (CARB) estimates the incremental cost of fuel cell vehicles versus conventional vehicles to be \$120,000 to \$300,000 during the next four to eight years, and \$9,300 thereafter on the assumption that sales volume would justify larger volume production.⁹²

Another issue is the challenge of producing and delivering enough hydrogen to fuel a fleet of fuel-cell vehicles. Hydrogen generated through the reformation of fossil fuels undermines the potential of hydrogen to limit the nation's dependence on fossil fuels and also results in significant emissions of air pollutants. Electrolysis requires the use of a great deal of electricity. Should that electricity come from renewable sources, the entire process is emission-free from "well to wheels." But if it comes from fossil fuels—as is likely in the near term—the potential for significant pollution continues to exist.

Distribution of hydrogen would require the installation of equipment to create hydrogen at filling stations or the development of a system of hydrogen pipelines. New filling stations capable of dispensing hydrogen would also need to be created.

A final challenge is the availability of substances to act as catalysts for the chemical reaction that creates electricity in the fuel cell. Currently, platinum is the primary substance used as a catalyst. Platinum is generally expensive, experiences wide price swings, and is supplied in large quantities by only two countries—South Africa and Russia.⁹³ Moreover, there is concern that the high demand for platinum that would result from the widespread introduction of fuel-cell vehicles could spark worldwide shortages of the metal.

Future Prospects

While the future prospects of fuel-cell vehicles are uncertain, there are promising signs.

Both Honda and Toyota began leasing

a small number of vehicles for testing in California in late 2002. The California Fuel Cell Partnership—a public-private partnership—reports that 41 fuel-cell vehicles are currently operating in California.⁹⁴ Meanwhile, the first hydrogen filling stations have been built in California, Arizona and Nevada.⁹⁵

Automakers, government researchers and Maryland universities are intensifying their research efforts into fuel-cell vehicles. In 2003, President Bush announced the proposed investment of more than a billion dollars into fuel-cell and hydrogen research.

Not all of that research, however, has been focused in ways that reduce economic and environmental risks. For example, the Bush administration's hydrogen research strategy has been heavily tilted toward the production of hydrogen from coal and nuclear sources—both of which produce significant environmental damage. Spending on fossil fuel and nuclear hydrogen research has increased dramatically over the past several years, and now represents more than one-third of Department of Energy spending on hydrogen-related programs.⁹⁶

Ultimately, it will take several research breakthroughs to solve the range, refueling, cost and materials availability problems posed by fuel cells—followed by the investment of billions of dollars in a new refueling infrastructure for the vehicles. Needed investments will be more likely to occur if an initial market for the vehicles is guaranteed, as is the case under LEV II. And they will be more likely to have a positive environmental impact if those investments are focused on encouraging the use of renewably generated hydrogen in vehicles.

Getting Advanced Technology Vehicles on the Road: The LEV Program

Despite the great advances in clean car technologies over the past decade, Maryland consumers are hard pressed to find advanced-technology vehicles in their local car showrooms. With the partial exceptions of hybrid-electric cars (of which only three models are currently available) and natural gas vehicles (generally available only to fleet purchasers), few advanced-technology vehicles are available for sale to Maryland residents.

The most effective way to promote the sale of advanced-technology vehicles in the state would be adoption of California's Low-Emission Vehicle II program.

History

The LEV II program has its roots in an unusual provision 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 models 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. Several states, such as Massachusetts and New York, took advantage of that opportunity by adopting the LEV program in the early 1990s. Most recently, New Jersey,

Rhode Island and Connecticut have also moved to adopt the program.

In California, the LEV program has evolved. As the initial 1998 compliance date for the original LEV program crept nearer, California moved to add flexibility to the program. The original 1990 LEV 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 2000.⁹⁷

In 1998, CARB amended the program again and created the LEV II program to allow manufacturers to receive partial ZEV (PZEV) credit for near-zero-emission vehicles. In 2001, CARB again revised the program to encourage the development of advanced-technology vehicles and to allow manufacturers to claim additional credits toward compliance with the program. 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 LEV requirement in Massachusetts, New York, and Vermont to the 2005 model year. (Note that car model years are not synchronized with the calendar year: 2005 model year vehicles go on sale in calendar year 2004.)

Implementation of the program in California itself was pushed back until model year 2005 when a federal district court judge in California issued a preliminary injunction in June 2002 preventing the implementation of the 2001 amendments to the LEV program in that state

for the 2003 and 2004 model years.⁹⁸ The injunction was based on a narrow legal argument made by automakers that one of the 2001 amendments represented a fuel economy standard, which states are not permitted to set under federal law.

California officials appealed the ruling, but also went back to the drawing board to come up with further revisions to the plan. The proposed changes approved by CARB in April 2003 represent the most sweeping changes to the program since its adoption—virtually eliminating the requirement for the sale of “pure” zero-emission vehicles in the near term, while boosting requirements for the sale of hybrid-electric or other advanced-technology cars.

How It Works

LEV II technically requires that 10 percent of all vehicles sold in California be zero-emission vehicles beginning in model year 2005. In actuality, though, percentages of vehicles called for under LEV II do not represent real 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.

The key elements of the program are as follows:

Pure ZEVs

LEV II now has smaller requirements for the sale of “pure ZEVs”—those vehicles with no tailpipe or fuel-related evaporative emissions—than the original program. Changes approved by CARB in January 2004 would require automakers to sell approximately 250 hydrogen fuel-cell vehicles nationwide between model years 2005 and 2008. The fuel-cell vehicle requirement would increase to 2,500

nationally between model years 2009 and 2011, and then to 25,000 vehicles in California between model years 2012 and 2014, and 50,000 vehicles in California between model years 2015 and 2017.⁹⁹

LEV II would not require the sale of any additional fuel-cell vehicles in Maryland until 2012 at the earliest. However, adopting LEV II in Maryland would allow automakers to claim California credit for fuel-cell vehicles placed in Maryland, increasing the likelihood that a limited number of fuel-cell vehicles would find their way onto the state's highways. In addition, beginning in 2012, automakers would be required to sell several hundred fuel-cell vehicles per year in Maryland, with the numbers increasing steadily thereafter.¹⁰⁰

Automakers still retain the option of providing battery-electric vehicles to meet the pure ZEV requirement. Automakers can meet one-half of their fuel-cell vehicle obligations under the new program with the sale of battery-electric vehicles, with 10 battery-electrics earning the same credit as a single fuel-cell vehicle. In early years of the program, manufacturers can earn significant credits toward compliance either through the sale of full function battery-electrics, 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 model year 2006 they will count for only 0.15 of a full-function ZEV.¹⁰¹

Partial ZEV (PZEV) Credits

The law allows manufacturers to meet up to 6 percent of the 10 percent ZEV requirement by marketing ultra-clean conventional, gasoline-powered cars. To receive partial ZEV, or PZEV, credit, vehicles must meet LEV II's strict super-low-emission vehicle (SULEV) emission

standards, have "zero" evaporative emissions, and have their emission control systems certified and under warranty for 150,000 miles.¹⁰² Intermediate volume manufacturers—those that sell fewer than 60,000 light- and medium-duty vehicles in California annually—may meet the entire LEV percentage requirement with PZEV credits.¹⁰³ Each PZEV receives a credit equivalent to 0.2 of a pure ZEV.

Advanced-Technology PZEVs (AT-PZEVs)

Manufacturers are allowed to satisfy up to four percentage points of the 10 percent ZEV requirement by marketing vehicles that meet PZEV criteria and that also include advanced features such as hybrid-electric drive or run on alternative fuels such as compressed natural gas. (Manufacturers who choose to sell enough zero-emission vehicles to equal two percent of their sales volume can reduce their AT-PZEV sales to two percent.)

The value of an AT-PZEV under the program is determined by adding credits earned through a variety of advanced technologies to the baseline PZEV credit of 0.2.

- **All-electric range** – Vehicles that can travel at least 10 miles in electric mode (such as plug-in hybrids) are eligible for credits ranging from approximately 1 to 2.25 for a vehicle with 90-mile all-electric range.
- **Alternative fuel** – Vehicles that run pressurized gaseous fuel (such as compressed natural gas) are eligible for a credit of 0.2. Vehicles capable of running entirely on hydrogen are eligible for a credit of 0.3.
- **Hybrids** – Vehicles that include an advanced battery integral to the operation of the vehicle are eligible

for additional credit. The credits are determined based on the voltage and amount of power provided by the hybrid system. Additional credits for high-voltage hybrid-electric vehicles range from 0.2 to 0.5.

- **Clean fuels** – Vehicles that operate on fuels with very low emissions over their entire fuel cycles are eligible for a credit of up to 0.3.¹⁰⁴

The current 2004 Toyota Prius and Honda Civic hybrid are the first gas-powered hybrid vehicles to meet AT-PZEV standards. Honda’s natural-gas powered Civic GX also meets AT-PZEV standards.

Other Features

Under the California rules, automakers can also receive credits for placing vehicles in demonstration programs, and can earn additional credit for placing vehicles in programs that allow for shared use of vehicles and use “intelligent” transportation technologies (such as reservation management or real-time wireless information). Additional credits are available if the vehicles are linked to transit use.

In the initial years of the program, LEV II applies only to passenger cars and the lightest light trucks. Beginning in model year 2007, heavier sport utility vehicles, pickup trucks and vans sold in California will be phased into the sales figures used to calculate the LEV requirement.

Another important change adopted by CARB in 2001 is a gradual ratcheting up of the LEV requirement from 10 percent to 16 percent over the next two decades, as shown in Table 5. However, the ample opportunities for additional credits and multipliers available to manufacturers will significantly reduce the number of zero emission vehicles that must be sold, particularly in the early years of the program.

Table 5: California LEV Percentage Requirement¹⁰⁵

Model Years	Minimum LEV Requirement
2005-2008	10 percent
2009-2011	11 percent
2012-2014	12 percent
2015-2017	14 percent
2018-	16 percent

The complexity of the LEV II credit scheme makes it impossible to predict how many of each type of vehicle will be on the road, but the state of California has estimated the number of vehicles sold that would be AT-PZEVs and PZEVs. Assuming the same percentage of vehicles would be sold in Maryland, and assuming that the state would adopt identical requirements to those in place in California for the 2008 and subsequent model years, carmakers would sell 89,000 AT-PZEVs and 477,000 PZEVs between 2007 and 2010. (See Table 6.)

Table 6: Estimated Sales in Maryland Under ZEV Program¹⁰⁶

Model Year	AT-PZEVs	PZEVs
2008	16,178	101,821
2009	22,276	114,667
2010	24,399	124,983
2011	26,582	135,300
Total Sales	89,435	476,771

Adoption of LEV II, therefore, would result in the sale of hundreds of thousands of vehicles in Maryland with hybrid-electric motors, advanced emission-control systems, and other advanced automotive technologies. And it would put the state in position to take advantage of further advances in the years to come, by requiring the sale of hundreds of “pure ZEVs” beginning as early as model year 2012.

Benefits

The experience of the last three decades has shown that automakers will refuse to install technology that improves fuel economy or reduces emissions unless required to by law—despite consumers’ stated desire for more environmentally benign vehicles. LEV II gives consumers access to emission control technologies and promotes further technological development that will result in even cleaner cars in the future.

LEV II achieves four important goals in hastening this technological shift.

Ensuring a Supply of Clean Vehicles

As noted above, consumer reaction to many types of advanced-technology vehicles has been positive. Yet, in Maryland, it is virtually impossible for consumers to purchase battery-electric vehicles and exceedingly difficult for them to purchase (and refuel) natural gas-powered vehicles. Ultra-clean conventional vehicles that meet PZEV standards are beginning to be offered for sale in states such as New Jersey and New York that have ZEV programs, but there is no guarantee of their availability in Maryland. Even hybrid vehicles are in short supply, and the available choices of vehicle types are extremely limited.

LEV II guarantees that consumers will have the opportunity to purchase these vehicles by requiring automakers to supply them. At the same time, the flexibility in the program gives automakers ample options to supply those vehicles that best reflect their market strategies.

Setting High Standards

Just because a vehicle runs on an alternative fuel or utilizes an advanced technology does not mean that it is significantly more beneficial for the environment.

Over the last decade, numerous incentive programs have been created at the federal level and in the states to promote the purchase of alternative-fuel vehicles—with minimal environmental results. Meanwhile, some of the designs for hybrid-electric vehicles proposed by major automakers would have little real impact on emissions, but could lead to further improvements in vehicle power.

By requiring all vehicles certified under the program to meet aggressive emissions targets, ensuring that emission-control technologies last for the expected life of the vehicle, and promoting standards for emerging technologies such as hybrid-electric vehicles, LEV II sets a high bar for advanced technologies to meet, ensuring that vehicles sold under the program bring solid environmental benefits.

Allowing for Investment in Infrastructure

Advanced-technology vehicles—and alternative-fuel vehicles in particular—have long been hamstrung by the lack of appropriate infrastructure to promote their use, particularly facilities for refueling. This has created a “chicken and egg” problem in which consumers do not purchase alternative-fuel vehicles because there is nowhere to refuel them, while potential entrepreneurs do not build refueling stations because there are no vehicles to use them.

The latest changes to the LEV program reduced the need for new refueling infrastructure for ZEV-compliant vehicles. The vast majority of vehicles required under the revised program would be conventional PZEVs and hybrid-electric vehicles, both of which run on gasoline.

However, automakers still retain the option of meeting the program’s requirements by selling battery-electric, natural gas, fuel-cell and other types of vehicles

that do not run on gasoline. Should automakers choose this compliance path, LEV II would ensure that a sufficient number of vehicles are sold within the state to support the development of an appropriate refueling infrastructure.

Guiding Technology

The LEV program has traditionally been thought of as a “technology forcing” program—driving automakers to invest in research and development efforts to create cleaner, environmentally preferable automobiles.

In this regard, the LEV program has thus far been a rousing success. For example, prior to California’s 1990 adoption of the LEV program, the number of patents issued for electric vehicle-related technologies was declining by about one patent per year. Immediately following the adoption of the LEV program, the amount of patent activity skyrocketed: between 1992 and 1998, the number of EV-related patents increased by about 20 patents per year.¹⁰⁷ More recently, a similar trend has been documented for fuel-cell vehicle-related patents.¹⁰⁸

The technological advances represented by those patents led to dramatic improvements in battery and electric-drive technologies—many of which are now used in hybrid-electric vehicles and could soon have relevance to the development of hydrogen fuel-cell vehicles. Indeed, had the LEV program not been in existence, it is doubtful that these technologies would be as advanced as they are today.

The recent changes to LEV II that lower requirements for the number of “pure” ZEVs reduce—but do not eliminate—this technology-forcing component of the program. The program’s increasing goals for the development of fuel-cell vehicles will continue to act as a driver for the development of this and

related technologies. Meanwhile, the program will work to bring clean conventional vehicles and hybrid-electrics to the point of mass commercialization.

As a result, LEV II could be more accurately referred to as a “technology guiding” program, pushing automakers to invest in bringing to market those technologies with a proven ability to achieve environmental benefits.

Cost

Critics of LEV II often suggest that the costs of the program to automakers and consumers would be too steep. Advanced-technology vehicles, some argue, may be technologically feasible, but are too expensive to survive in the marketplace.

With the most recent changes to LEV II, however, any such concerns about cost are no longer valid. The adoption of LEV II in Maryland would likely require the manufacture of no additional “pure ZEVs” such as battery-electric or fuel-cell vehicles—the most expensive vehicles to produce—until model year 2012 at the earliest. Automakers would retain the option to produce such vehicles—and earn extra credit toward LEV II compliance—in the meantime.

Instead, automakers will be required to sell thousands of vehicles with broad and proven consumer appeal—hybrids and clean conventional vehicles—and may choose to supply other advanced-technology cars such as natural gas vehicles. The incremental cost of these technologies—particularly PZEVs—is modest when compared to the base cost of the vehicles and automakers’ annual sales. In addition, the seven states that have adopted or are in the process of adopting the LEV II standards represent 26 percent of the national car and light truck market.¹⁰⁹ This means that manufacturers already have invested in research and production facilities.

Cost to Manufacturers

Assuming the requirements for vehicle sales in Maryland presented above, and CARB's estimates for the cost of complying with those requirements using clean conventional cars and hybrids, the adoption of LEV II in Maryland would cost automakers approximately \$34.4 million in model year 2008 in technological improvements. Incremental costs would rise to \$45.4 million in model year 2011.¹¹⁰ (See Table 7.)

Table 7: Estimated Cost of LEV II Compliance in Maryland (in millions)

Model Year	AT-PZEV	PZEV	Total
2008	\$24.3	\$10.2	\$34.4
2009	\$26.7	\$11.5	\$38.2
2010	\$29.3	\$12.5	\$41.8
2011	\$31.9	\$13.5	\$45.4

These costs translate to an additional \$290 per ZEV-compliant model year 2008 vehicle sold or an average of \$110 per light-duty vehicle sold in Maryland.

To further put these figures in perspective, the estimated cost to automakers in 2007 represents 0.004 percent of the gross sales of the six major manufacturers in 2003. And \$34.4 million is a minor expense compared to the nearly \$19 billion in profits those automakers earned in 2003.¹¹¹

Even these estimates grossly overstate the potential cost to automakers of LEV II. In fact, LEV II has several tangible financial benefits for automakers that offset much of these costs.

First, vehicles sold under LEV II can be used by automakers toward compliance with other federal and state regulatory requirements. Should Maryland adopt the LEV II program, automakers could use the ZEV and SULEV certified vehicles in their fleets to ease their compliance with LEV II's requirements

for emissions of non-methane organic compounds, ozone-forming nitrogen oxides and other pollutants. Similarly, the hybrid vehicles sold under LEV II—if they prove to be more fuel efficient—could help automakers comply with federal corporate average fuel economy (CAFE) standards. In other words, the manufacture and sale of ZEV-compliant vehicles makes it less likely that automakers will pay fines for failure to comply with other laws, or will allow them to sell additional larger vehicles with higher profit margins. In either case, LEV II creates an offsetting financial benefit for automakers.

In addition, financial benefits will accrue to automakers through the “spinoff” of advanced technologies to other vehicle lines. Technologies developed for the Toyota RAV4-EV, for example, have been used in the 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.¹¹²

Finally, and perhaps most importantly, consumers have demonstrated a willingness to pay more for ZEV-compliant vehicles. Sales of the first generation of hybrid-electric vehicles have been strong, despite a cost premium of as much as \$3,000 to \$4,000 for the vehicles. A desire to help the environment, to avoid frequent trips to the gas station, or to be among the first to use a new technology all appeal to a significant segment of consumers—as does the prospect of substantial savings on the cost of fuel.

Consumer Costs and Benefits

While manufacturers will undoubtedly assume some additional costs as a result of LEV II, Maryland consumers will likely see little difference in vehicle prices, and many may benefit directly from the program.

In the case of clean conventional cars certified to the PZEV standard, there is little evidence of automakers passing on the additional cost of the vehicles to consumers. In California, for example, Toyota sells the same model Camry in both PZEV and non-PZEV versions, with no difference in price. Similarly, Honda markets a PZEV and non-PZEV version of the Accord, with a price differential of only \$150.¹¹³ As manufacturers arrive at less-costly means of meeting the PZEV standards, and as PZEVs are manufactured in greater quantities, these incremental costs should decrease. Some of the current costs may also reflect research and development and retooling expenses, which will ultimately be paid off. In addition, the 150,000-mile emission system warranty required under the PZEV standard protects consumers from any costs they might incur upon emission-system failure.

Hybrid-electric vehicles, on the other hand, will likely continue to come at a price premium for the foreseeable future. Whereas the price differential between hybrids and conventional vehicles is now about \$3,000 to \$4,000, CARB projects that the incremental cost of the vehicles will decline to about \$700 by the beginning of the next decade.¹¹⁴

Another potential benefit for consumers are government incentives for the purchase of advanced-technology vehicles. Federal incentives include tax deductions of \$2,000 to \$50,000 for purchase of clean fuel and hybrid 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. However, this incentive is scheduled to be phased out beginning in 2004 and will end entirely in 2007.¹¹⁵ 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 also is in the process of being phased out, and will end entirely in 2005.¹¹⁶

Maryland has offered several incentive programs targeted at individuals and businesses. The state has offered tax credits of up to \$2,000 for the purchase of a new electric vehicle and up to \$1,000 for the purchase of a qualifying hybrid electric vehicle. Private companies who wish to purchase clean-fuel vehicles for their fleets can also receive financial support from the state.¹¹⁷

The tax credit for individual cars, however, is due to expire in 2004. Renewal of the incentive would maintain this benefit for consumers and businesses who choose to purchase cleaner cars.

However, vehicle cost is just one element of the cost equation for consumers. Equally important are the savings in fuel expenses over the lifetime of the vehicle. Assuming a 30 percent improvement in fuel economy and gasoline prices of \$1.75 per gallon (well below the average price at the time this report went to press), a hybrid-electric car will save its owner more than \$1,000 (present value) in fuel costs.¹¹⁸ Should hybrid-electric vehicles continue to come down in price or gas prices to rise, the result would eventually be a net economic benefit for consumers who purchase the vehicles.

Environmental Benefits

As noted above, advanced-technology vehicles have the potential to achieve dramatically improved environmental performance compared to conventional vehicles. Quantifying the specific air quality impacts that would result from adoption of the program in Maryland is beyond the scope of this report, but analysis conducted for Northeastern states suggests Maryland would have much to gain from adoption of LEV II.

The Northeast States for Coordinated Air Use Management (NESCAUM), an association of state air quality agencies, performed an analysis of the air pollution benefits of LEV II versus the Tier 2 federal standards that would otherwise be in effect. While both LEV II and Tier 2 reduce air pollution, NESCAUM's analysis found that LEV II will provide an additional 25 percent reduction in toxic air emissions over Tier 2 standards by 2020. Hydrocarbon emissions will be reduced an additional 16 percent and carbon dioxide emissions will be reduced by an ad-

ditional 3 percent compared to Tier 2.¹¹⁹

These percentage emissions savings would apply to any state that adopted LEV II.¹²⁰ Thus it is clear that adoption of LEV II would result in significant reductions in emissions of toxic, smog-forming, and greenhouse gas pollutants, at minimal cost to automakers, and with significant benefits to consumers.

Moreover, adoption of LEV II would set Maryland on a path to enjoy the benefits of the next generation of cleaner vehicles as soon as they become available.

Policy Recommendations

Adopt LEV II

Adoption of the Low-Emission Vehicle II program would be beneficial public policy for Maryland. LEV II would provide public health benefits from reduced automotive pollution, enhance the state's energy security and stimulate research and development of clean car technologies. It is also a viable public policy, given technological advances in clean car technologies over the past decade and consumer demand for clean vehicles.

Other Measures

Maryland can also adopt other measures to enhance the spread of clean vehicle technologies within the state.

Maryland should offer tax and other incentives for the purchase of zero-emission and near-zero-emission vehicles.

Current state and federal incentives for the purchase of advanced-technology vehicles can help spur consumer and business demand for these vehicles. State tax incentive programs—such as the tax credit of up to \$2,000 for the purchase of an electric or hybrid vehicle—should be renewed and expanded to provide further

incentives for the purchase of the cleanest hybrid-electric vehicles. (Hybrid vehicles in which the electric motor simply boosts performance or provides a mild improvement in fuel economy should not be included.) In addition, Maryland should consider other creative measures to reward the purchase of cleaner cars, such as always allowing hybrid vehicles in HOV lanes and offering reduced vehicle registration fees.

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

Public awareness of zero- and near-zero-emission vehicles in Maryland is low, but a public education plan leading up to the launch of LEV II could play a key role in the program's success. Such a program should not only clearly extol the environmental benefits of advanced-technology vehicles, but should also promote the benefits to consumers and dispel the common misperceptions about advanced-technology vehicles, 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.

Glossary of Abbreviations

AT-PZEV – Advanced technology partial zero-emission vehicle credits.

CARB – California Air Resources Board. Body charged with setting vehicle emissions standards in California.

CNG – Compressed natural gas.

CO₂ – Carbon dioxide.

EV – Battery-electric vehicle.

LEV II – Low-Emission Vehicle II program. Includes stringent limits on emissions from light- and medium-duty vehicles and the LEV requirement.

LNG – Liquid natural gas.

MMTCE – Million metric tons of carbon equivalent, a measure of greenhouse gas emissions.

MOA – Memorandum of Agreement negotiated between CARB and six major automakers in 1996 that eliminated interim ZEV requirements for 1998-2003 model years.

MPG – Miles per gallon.

NO_x – Nitrogen oxides.

PZEV – Partial zero-emission vehicle credits.

SULEV – Super-low-emission vehicle; the second-cleanest emission bin under LEV II and a prerequisite for qualification for PZEV credit.

ULEV – Ultra-low-emission vehicle; the third-cleanest emission bin under the LEV II program.

VOC – Volatile organic compounds.

ZEV – Zero-emission vehicle.

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