Ready to Roll

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

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Executive Summary

Despite tighter automobile emission standards over the last three decades, Washington 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 Washington's contribution to global warming and enhancing the state's energy security.

Policies such as the Clean Cars program, which requires the sale of low- and near-zero-emission vehicles and establishes standards for global warming pollution from vehicles, can help bring increased numbers of advanced-technology vehicles to the state.

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

- Concentrations of air toxics such as benzene and formaldehyde raise Washington residents' cancer risk above federal health goals (p. 9).
- During the summer of 2003, air pollution monitors in Washington registered three instances when smog levels exceeded EPA health standards. Light-duty vehicles such as cars, pick-up trucks, minivans and sport utility vehicles (SUVs) are responsible for almost one half of all emissions of nitrogen oxides and volatile organic compounds (VOCs) to the air. Nitrogen oxides and VOCs are the chemical components of smog (p. 10).
- The transportation sector, including cars and light trucks, is responsible for nearly half of Washington's emissions of greenhouse gases, which cause global warming. Global warming poses severe potential threats to mountain snowpack and the state's water cycle, coastal and forest ecosystems, and public health (p. 10).
- Washington'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 as global petroleum supplies tighten.

Advanced-technology vehicles can alleviate many of these problems.

- Advanced-technology vehicles can significantly reduce emissions of air toxics and smog-forming pollutants from Washington cars and light trucks. The current generation of hybrid-electric vehicles—such as the Toyota Prius, the Ford Escape and the Honda Civic—are much cleaner than the average vehicle on sale in Washington today (p. 16). Clean conventional vehicles with state-of-the-art emission-reduction technology are now being manufactured that attain similar air toxics and VOC pollution reductions (p. 19).
- Advanced-technology vehicles can also reduce Washington's emissions of greenhouse gases, which cause global warming. Vehicles that take advantage of the benefits of hybrid-electric motors and other advances in automotive technology can produce about one-third less global warming-inducing carbon dioxide per mile than conventional vehicles (p. 21).
- Advanced-technology vehicles can enhance Washington's energy security by improving fuel efficiency or by using alternative fuels such as natural gas, electric power or renewably generated hydrogen.

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

- **Hybrid-electric vehicles:** About 85,000 hybrid-electric vehicles were sold in the U.S. in 2004, an increase of 63 percent over the previous year. As many as 60 percent of potential vehicle buyers surveyed stated that they would consider buying a hybrid, yet Washington auto dealers report waiting lists of six months for the popular Toyota Prius hybrid (p. 17-18).
- **Clean conventional vehicles:** Thirteen automakers now manufacture vehicles that meet California's rigorous partial Zero Emission Vehicle (PZEV) emission standards. However, many of these vehicles have been made available only to consumers in states that have adopted the Clean Cars program (p. 21-23).
- **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 (p. 25-26).
- Other types of vehicles—such as **battery-electric vehicles, "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 on the broad automobile market.

Adopting the Clean Cars program would put tens of thousands of advanced-technology cars, light trucks, and SUVs on Washington's roads by the end of the decade, at minimal additional cost to automakers and potential net benefit to consumers. One component of the program is known as the Low-Emission Vehicle program, or LEV II.

- The LEV II program would require automakers to sell approximately 12,000 hybrid-electric vehicles and 52,400 clean conventional gasoline-powered vehicles in Washington in 2008 (when model year 2009 vehicles go on sale, and assuming no significant growth in total car sales), with the numbers increasing over time (p. 37).
- Producing vehicles to meet these targets would cost automakers approximately $19.5 million in 2008. The incremental cost of the program in 2008 represents 0.0025 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 vehicles with reduced emissions (p. 40-41).
- Consumers are unlikely to be negatively affected by the program. 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 (p. 41-42).
- 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 (p. 40).

Another part of the Clean Cars program, vehicle global warming pollution standards, will begin reducing the contribution of automobiles to greenhouse gas pollution in 2008 in states that adopt the standards.

- The vehicle global warming pollution standards seek to "achieve the maximum feasible and cost effective reduction of greenhouse gas emissions from motor vehicles." Limits on vehicle travel, new gasoline or vehicle taxes, or limitations on ownership of SUVs or other light trucks cannot be imposed to attain the new standards (p. 42).
- By 2012, the standards could reduce greenhouse gas emissions from new cars by 25 percent and from new light trucks by 18 percent. These emissions reductions would save consumers money by reducing vehicle operating costs (p. 43).

Adoption of the Clean Cars program is essential to getting clean, advanced-technology vehicles onto Washington's roads.

Photo: NREL/DOE

The hybrid-electric Honda Insight is the most fuel efficient vehicle sold in the U.S.

- The program would reduce emissions of smog-forming, toxic and global warming pollution.
- The program also would ensure a consistent supply of clean vehicles for Washington's 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 the programs are attainable and achieving them would be beneficial to Washington.

INTRODUCTION

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

Hybrid-electric vehicles—virtually unknown 10 years ago—have begun to make their way onto Washington'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 pollution)—a far cry from 10 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 pilot models of new vehicles types—such as "plug-in" hybrids that fuse the benefits of hybrid-electric and battery-electric vehicles—are being road-tested. This technological progress would probably not have occurred were it not for the existence of stringent emissions standards designed to push the technology forward.

The promise of a new generation of cleaner, more environmentally benign cars has never been brighter. Yet, the vast majority of vehicles sold in Washington today do not incorporate the latest in advanced technology. Even worse, many of the most promising advanced-technology vehicles cannot be easily purchased by Washington 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 Washington's roads will require more than just financial incentives. For years, buyers of alternative-fuel vehicles have been eligible for federal tax breaks and other benefits. Yet, for the most part, the vehicles have simply not been made available to the general public and facilities for refueling those vehicles are scarce. 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. The state of California has enacted a Clean Cars program, which has two components: the Low-Emission Vehicle program (LEV II) and vehicle global warming pollution standards. The LEV II program can increase the number of low-emitting vehicles on Washington's roads because it requires each of the major automakers to sell significant numbers of hybrid-electric, clean conventional, and other advanced-technology cars in the near future. The vehicle global warming pollution standards would require car manufacturers to reduce carbon dioxide emissions from vehicles beginning in 2008. In addition to putting more of today's advanced-technology vehicles on the road, the Clean Cars program has the potential to 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 Clean Cars program's unique approach, seven northeastern states have adopted the LEV II

Photo: Electric Vehicle Association of Canada

Refueling a natural gas van.

component for themselves and many are preparing to adopt vehicle global warming pollution standards.

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 pollution to the atmosphere.

Washington cannot afford to let this revolution pass us by.

This report will explain why, beginning with an explanation of why we need advanced-technology vehicles. The following section discusses what advanced technology vehicles are available today, how they are being received by consumers, and their future prospects. The next section reviews technologies that are likely to be available in the future. We then analyze how adopting the Clean Cars standards would result in increased use of these advanced technology vehicles in Washington. The report concludes with policy recommendations.

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.

Air Quality

Toxic air contaminants pose severe threats to the health of thousands of Washington residents. With many Washington 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 Washington residents. Among the air toxics released from cars, light trucks, and SUVs are:

- **Benzene,** which can cause leukemia and a variety of other cancers, as well as central nervous system depression at high levels of exposure.
- **1,3-Butadiene,** a probable human carcinogen, which is suspected of causing respiratory problems.
- **Formaldehyde,** a probable human carcinogen with respiratory effects.
- **Acetaldehyde,** a probable human carcinogen that has caused reproductive health effects in animal studies.

In the Clean Air Act amendments of 1990, Congress set a goal of reducing the cancer risk from airborne toxins to one case of cancer for every one million residents following a lifetime of exposure. Yet in 1996 (the most recent year for which comprehensive data are available), concentrations of air toxics in Washington's air were sufficient to pose a statewide average cancer risk of one new case for every 21,277 residents—well above the health-based goal. Residents of every Washington county were exposed to levels of benzene and formaldehyde that exceeded the one-in-a-million cancer risk goal. Pollution from mobile sources (including cars, trucks and off-road equipment) accounted for significant portions of the added cancer risk.[2] (See Table 1.)

Residents of several Washington counties are at particular risk. King and Clark

Table 1. Health Risk from Air Toxics Exposure in Washington[3]

	Estimated Average Human Exposure Concentration (micrograms per cubic meter)	Factor by which Estimated Exposure Exceeds Health-Based Goal*	Percent of Added Cancer Risk from Mobile Sources
Acetaldehyde	0.51	1	91%
Benzene	1.59	12	58%
1,3-Butadiene	0.05	1	88%
Formaldehyde	0.7	9	62%

*Potential added cancer risk per million exposed individuals.

counties rank in the worst 5 percent of the nation's counties for cancer risk from airborne toxics. Spokane, Kitsap, Snohomish, Pierce, and Cowlitz counties are only slightly better, ranking in the worst 25 percent.[4]

Smog

During the summer of 2003, air pollution monitors in Washington registered three instances in which air quality failed to meet EPA health standards for ground-level ozone, better known as smog.[5]

Smog is formed as a result of a chemical reaction involving sunlight, nitrogen oxides (NOx), 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] In King County, one of the state's most heavily populated counties, approximately 10 percent of children have asthma.[7]

On-road motor vehicles are major contributors to the smog problem. Nationally, cars, pick-up trucks, vans and SUVs—otherwise known as light-duty vehicles—are responsible for nearly one-half of all NOx and VOCs emissions.[8] In Washington, transportation sources are responsible for 55 percent of all air pollution.[9]

Global Warming

Carbon dioxide and other greenhouse gases pose serious threats to the health of Washington's residents. Over the last century, the average annual temperature in Ellensburg has increased by 1° F. In some parts of the state, precipitation has increased by 20 percent.[10] 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.[11] Further, these recent warming trends cannot be explained by natural variables—such as solar cycles or volcanic eruptions—but they do correspond to models of climate change based on human influence.[12]

Should the concentration of greenhouse gases continue to increase over the next century, Washington could see a further 2° F to 9° F increase in average temperature and a 10 percent increase in wintertime precipitation.[13]

These changes will have a significant effect on the environment and our way of life. One of the most serious consequences for Washington is how global warming could decrease the mountain snowpack and alter annual water flows. By 2050, the annual snowpack may shrink to half its current size, reducing summer and fall river levels that could affect hydropower generation, salmon survival, and shipping.[14] Other potential impacts include increased winter storm-related deaths, coastal flooding, beach erosion, loss of wetlands and tidal flats, and alteration of forest and other ecosystems that would shift the range of many plants and animals.[15] Changes to forests could include a 15 to 25 percent decline in forests, especially east of the Cascades.[16] 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 2000, Washington released approximately 109 million tons of carbon dioxide equivalent (MTCO2E) of greenhouse gas pollution to the atmosphere. Of that amount, 48.8 MTCO2E—or approximately 48 percent—came from mobile sources such as cars and trucks.[17] These emissions will rise in the coming decades. Emissions from all transportation sources in the Puget Sound region are expected to increase by 24 percent by 2020.[18]

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.

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 record highs are due to economic growth in developing countries, instability in the Middle East, and supply limits in many oil-producing countries. 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.[19] 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.[20]

While pollution-control mechanisms for cars and trucks have reduced some of the impacts from vehicles, many impacts 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.

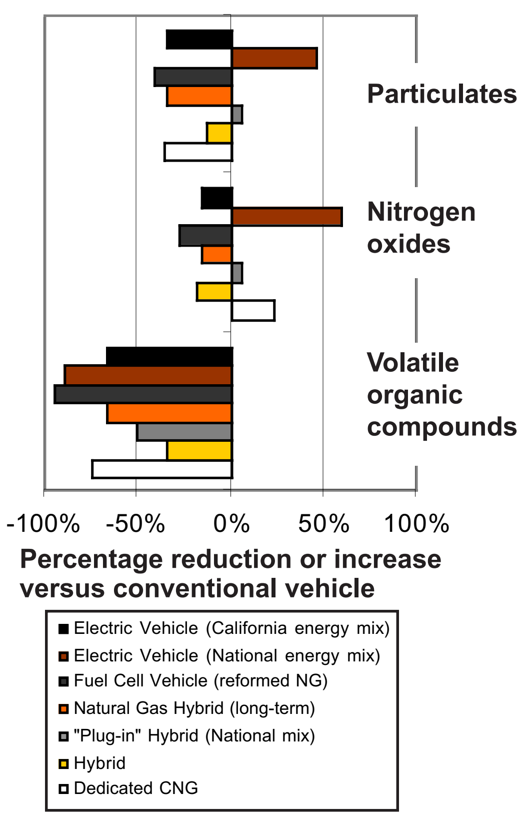
While there are many types of automotive technologies and alternative fuels that are environmentally beneficial, this report will focus on several technologies with clear environmental benefits that are either available to the public now, or could be available in the near future.

- **Hybrid-electric vehicles** – Hybrid-electric vehicles, such as the Toyota Prius, Ford Escape and Honda Civic, use an on-board electric motor to assist the vehicle's gasoline-powered engine, 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 reduced global warming gas emissions.
- **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 constraints mean that fuel cell vehicles will not be available to consumers in the near future.

Figure 1. Per-Mile Emissions of Advanced-Technology Vehicles[22]



Emissions from Different Technologies

Researchers with the Argonne National Laboratory 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."[21] Their analysis shows advanced technology vehicles can have lower emissions of air toxics, smog-forming chemicals, and global warming gases, and can reduce our reliance on fossil fuels.

Emissions of Air Toxics and Smog

The use of advanced technologies can significantly reduce toxic and smog-forming 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 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 Laboratory 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 and petroleum. (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 and hydrogen formed from nuclear energy creates radioactive waste that will remain dangerous for hundreds of years.

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. Further, though hydrogen-powered vehicles can be virtually emission-free if the hydrogen is generated by renewable energy, using renewable resources to power cars is a relatively inefficient use of clean power that could help offset demand for coal-fired and other dirty electricity sources.[23]

Emissions of Global Warming Gases

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, b) the vehicle's efficiency in using the fuel, and c) how many miles the vehicle is driven. (Vehicles also emit other greenhouse gas pollutants—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 Consumption

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

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

Figure 2. Per-Mile Carbon Dioxide Emissions of Advanced-Technology Vehicles[24]

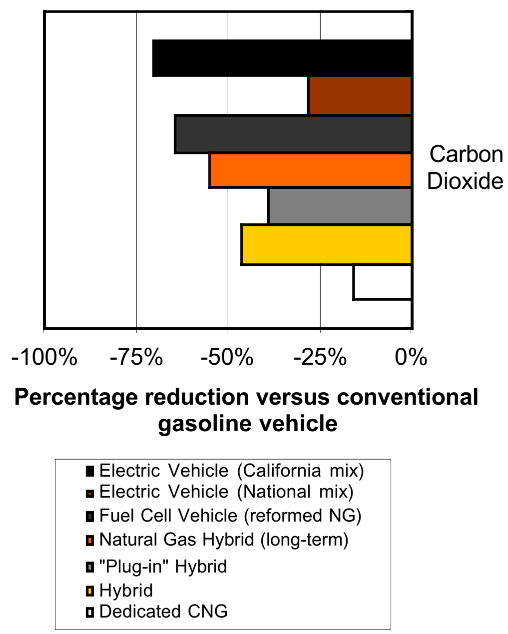
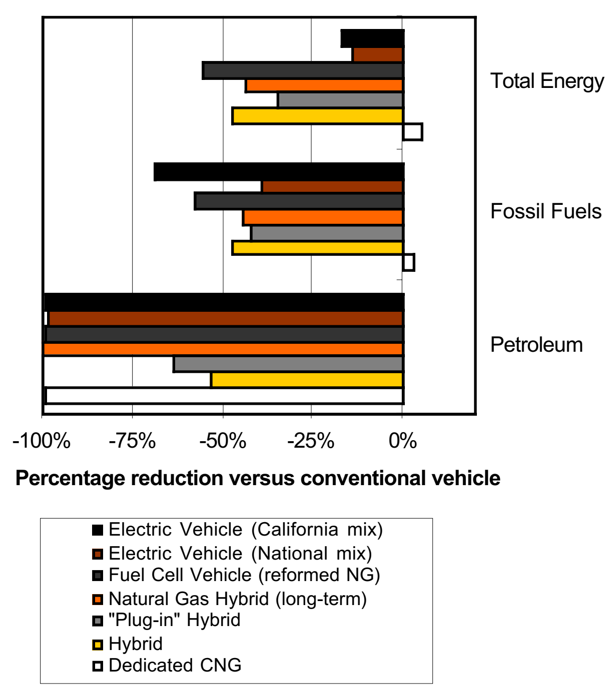


Figure 3. Per-Mile Energy Use of Advanced-Technology Vehicles[25]



The Need for Immediate Action

Washington residents drove 14 percent more miles on the state's highways in 2003 than they did in 1993.[26] This trend is likely to continue and, as a result, Washington will continue to face major negative public health, environmental and economic consequences of automobile air pollution.

As shown above, advanced-technology vehicles can provide significant benefits to Washington. 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 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.

Hybrid-Electric Vehicles

The hybrid-electric vehicle is a relative newcomer to Washington'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 were again 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 powered by both an electric motor and a gasoline engine, 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. In 2004, Ford began selling the hybrid version of its Escape SUV and Honda began selling a hybrid version of its Accord sedan.[27]

Photo: Paul Madsen

The Toyota Prius was one of the first hybrid-electric vehicles introduced to the United States.

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 gasoline-powered 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.[28]

Many hybrids, including the Honda Civic and Ford Escape, lack one of the attributes listed above. The absence of this characteristic does not necessarily make one hybrid more beneficial for the environment than another. In fact, the most fuel-efficient vehicle for sale in the U.S.—the Honda Insight—cannot be driven with the electric motor only. Of greater importance to determining a vehicle's impact is the percentage of a vehicle's power that is derived from the electric motor.

Vehicles in which components of hybrid technology—such as idle shut-off and regenerative braking—are employed simply to add to the vehicle's performance and not reduce its environmental impact are known as "muscle hybrids." 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 as a "portable generator on wheels" because of its four 110-volt outlets.[29] The environmental benefits of this type of hybrid are minimal; the hybrid system in the Silverado, for example, boosts fuel economy by only 10 percent.[30]

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.

Full and mild hybrid-electric vehicles have demonstrated clear environmental advantages over conventional vehicles. The five model-year 2005 full and mild hybrid-electric vehicles achieved an average EPA-rated fuel economy of 46.6 miles per gallon (MPG)—significantly more than the nearest gasoline-powered vehicle.[31]

In addition, most of the 2005 hybrid models are certified as super-low emission vehicles (SULEVs) under the LEV II program, meaning that their emissions are 90 percent cleaner than the average 2005 model year car.[32] Like the Honda Civic hybrid and Toyota Prius, Ford's newly released hybrid Escape meets AT-PZEV standards, and the vehicle, though an SUV, is ranked as having the 12th best fuel economy of all vehicles surveyed.[33] AT-PZEVs meet SULEV emissions standards, have "zero" evaporative emissions, and offer an extended emission system warranty.

Evaluating Advanced-Technology Vehicles: The ZEV Program 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 zero-emission vehicles (ZEVs), which have no tailpipe emissions. The ZEV requirement, a critical component of the Clean Cars program, has subsequently been modified to allow credit for vehicles with extremely low emissions and has been adopted or is in the process of adoption by seven other states.

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

- Automobiles meeting the program's **super-low emission vehicle (SULEV)** standards release about 90 percent less smog-forming pollution than the average vehicle sold today.
- Vehicles that receive **partial Zero-Emission Vehicle (PZEV)** credit 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).

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, Honda, Ford, and General Motors have expanded the availability of their hybrid vehicles in the United States.

The availability of hybrids to the general public has increased significantly in the 2005 model year. Honda began selling a hybrid version of the Accord, Ford started selling its Escape hybrid, and General Motors is now selling to retail customers a limited number of pickup trucks with modest hybrid capability. (See Table 2.)

While hybrids still represent only a small percentage of new vehicle sales in the U.S., that could change in the years to come. Toyota, for example, plans to manufacture 50 percent more Prius hybrids in 2005 than in 2004.[34] Over the next 10 years, more than one million hybrid vehicles may be sold in the U.S.[35]

Hybrids have proven popular in Washington. As of January 2005, there were 3,580 hybrid vehicles registered in the state.[36] In Washington there are waiting lists of up to six months for hybrids.[37]

Five years after Japanese automakers introduced hybrids to the U.S., America's "Big Three" automakers are just beginning to introduce their first hybrid vehicles to the general public, though only in limited numbers.

• **Ford** - Ford has begun selling a hybrid version of its Escape SUV to the general public. The two-wheel drive version of the vehicle has an EPA fuel rating for in-city fuel economy of 36 MPG—an increase of more than 60 percent in-city and 24 percent highway fuel economy versus standard Escape models.[38] The Escape is the first SUV to take substantial advantage of hybrid technology. Ford performed much of the engineering work itself and supplemented that with several patents purchased from Toyota.[39] In January 2005, Ford announced that it will start selling a hybrid version of the Mercury Mariner SUV this year, a year earlier than originally scheduled.[40]

• **General Motors –** GM currently offers "muscle hybrid" versions of its Sierra and Silverado trucks.[41] In 2005, GM plans to introduce a hybrid version of its model year 2006 Saturn VUE SUV that will get up to 12 percent better gas mileage than the standard model.[42] The company has announced that it will include a variety of hybrid technologies in several sedans and SUVs between 2005 and 2007.[43]

Table 2. Model Year 2005 Hybrid-Electric Vehicles Currently Available to the General Public

Manufacturer	Model
Toyota	Prius
Honda	Civic
Honda	Insight
Honda	Accord
Ford	Escape
General Motors	Silverado*
General Motors	Sierra*

* "Muscle Hybrid"

• **DaimlerChrysler** – DaimlerChrysler is expected to introduce a hybrid-electric version of its Dodge Ram pickup truck late in 2005, but only 100 of these diesel-electric vehicles will be available in the 2005 model year and their sale will be restricted to commercial fleets.[44]

Toyota and Nissan recently announced that they are planning to produce their hybrid models in the U.S. By the end of 2006, Nissan expects to manufacture a hybrid version of its Altima sedan at a U.S. factory. Toyota has not decided which vehicles to make here. Honda is also considering a similar shift in manufacturing location.[45]

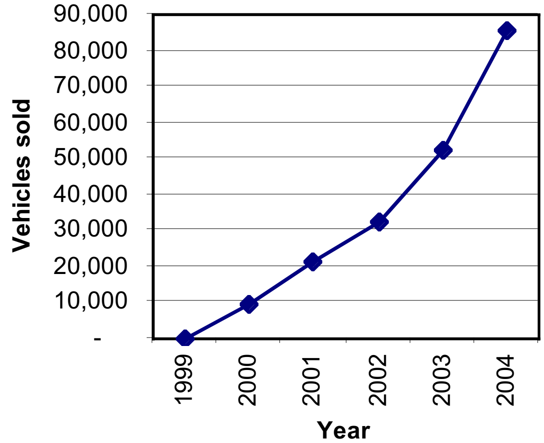
Consumer Acceptance

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 85,000 hybrids were sold in the U.S. in 2004, an increase of 63 percent from the previous year.[46] (See Figure 4.) Since 2000, hybrid sales have grown at an average annual rate of 74 percent.[47] As oil prices have risen, 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 Toyota reports that sales of the Prius doubled in 2004 compared to 2003.[48]

The market potential of hybrids has only begun to be tapped. A J.D. Power and Associates report found that 60 percent of new vehicle buyers would consider buying a hybrid-electric vehicle. Nearly one-third of those said they would buy a hybrid even if the added cost of the vehicle were not fully offset by fuel savings.[50] Yet, in part due to the failure of major American automakers to bring a hybrid to market until just this model year, the market is failing to satisfy consumers' desire for hybrid-electric vehicles.

Figure 4. Hybrid-Electric Vehicle Sales, U.S.[49]



- 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.[51] Toyota plans to increase production of the Prius by 50 percent.[52]
- More than 80,000 people expressed interest on Ford's Web site about the Escape hybrid, but Ford only intended to produce 4,000 hybrid Escapes for sale in 2004 and another 20,000 in 2005.[53] Ford anticipates waiting lists for the vehicles will be three to six months long.[54]
- General Motors plans to build only 2,500 of its model year 2005 hybrid Silverado and Sierra pickups. These hybrid pickup trucks will only be

available in Washington and five other selected states.[55]

- Lexus intends to sell its first hybrid SUV beginning in April 2005. Though no price has been announced, 9,500 vehicles have already been sold, 8,000 people are on waitlists, and 46,000 more people have expressed interest in the vehicle.[56] Lexus postponed the release of the SUV so that it could produce more vehicles and be better prepared to meet demand.[57]

Future Prospects

While existing hybrid-electric vehicles have demonstrated significant reductions in toxic air pollutants and global warming gases, 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.[58]

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 toxic and global warming pollution reductions versus conventional vehicles.

Clean Conventional Vehicles

Increasingly tight emission standards at the federal level and under California's Clean Cars standards 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 reductions in carbon dioxide emissions compared to today's vehicles, reducing Washington's global warming pollution and potentially improving the state's energy security.

Vehicle Characteristics

Achieving the Clean Cars program'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 emission 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.

Upcoming Hybrid Vehicles

With the market success of pioneering hybrid-electric vehicles such as the Toyota Prius, automakers are preparing to release many new hybrid vehicles to the market in the next several years.[59] These vehicles include:

- **Lexus RX400H**—Billed as the first luxury hybrid, the RX400H will incorporate a more powerful version of the Toyota hybrid system used in the Prius. Scheduled to debut in early 2005, the RX400H is expected to achieve a fuel economy rating of 28 MPG, compared to 21 MPG for its conventional equivalent.[60]
- **Toyota Highlander—**In mid 2005, Toyota plans to introduce a hybrid version of its Highlander SUV. It is expected to achieve similar performance to the Lexus RX400H.
- **Mercury Mariner**—In January 2005, Ford announced that it was stepping up production of its hybrid Mercury Mariner; the compact SUV is now expected to go on sale in late 2005.[61]
- **Nissan Altima**—Nissan plans to launch a hybrid version of its Altima sedan in the U.S. during 2006. The vehicle will use hybrid technology developed by Toyota.[62]
- **Saturn VUE**—Projected for launch in early 2006, the Saturn VUE hybrid is expected to achieve a fuel economy improvement of approximately 12 percent.[63]
- **Toyota Estima/Sienna**—Launched in the Japanese market in 2001 (marketed in Japan as the Toyota Estima Hybrid), the minivan has a fuel economy rating of 40 MPG. Although no launch date has been set, a hybrid Toyota minivan, most likely a hybrid version of the Sienna, is expected soon in the U.S.[64]
- **Other—**General Motors plans to introduce hybrid versions of the Chevy Malibu, as well as the Chevy Tahoe and GMC Yukon SUVs during model year 2007. Lexus intends to market a hybrid version of its LS430 sedan in 2007.[65] Ford plans to introduce the Ford Fusion and Mercury Milan sedans within the next three years.

- **Improved computerized control of the engine start-up sequence** to reduce "cold start" emissions (current emission-control systems are far less effective when cold).[66]
- **"Smog-eating" coatings** on radiators that convert ground-level ozone in ambient air into oxygen.[67]
- **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 air toxics and smog-forming chemicals are not the only potential benefits of applying advanced technology to conventional vehicles. A host of technologies exist that could dramatically cut emissions of greenhouse gases from today's vehicle fleets, allowing automobiles to meet global warming pollution standards.

Among the technological advances that can reduce global warming pollution are:

- **Smaller, more efficient engines**, made possible through the use of turbocharging, in which a turbine recaptures the 25 to 50 percent of an engine's energy that is lost through exhaust and redirects it into the engine; or through variable compression ratios that allow an engine to tailor compression rates to load conditions.[68]
- **Direct-injection engines** that allow greater control of the engine's use of fuel.[69]
- **Advanced transmissions—**such as five- and six-speed automatics and continuously variable transmissions—that allow a broader range of gear ratios.[70]
- **Integrated starter-generators** that allow greater power and enable the vehicle to take advantage of some features of hybridization (such as idle-off).[71]
- **Improved air conditioning systems,** which may include a more efficient compressor, leak less, and use a refrigerant that contributes less to global warming.[72]
- **Weight reduction**, achieved through the use of lightweight materials such as high-strength low-alloy steel, aluminum, or magnesium alloys, or redesign to use less material in a car.[73]
- **More aerodynamic designs,** which can include a modified body shape or covers below the vehicle to reduce air drag.[74]
- **Cylinder deactivation** technology, which turns off half of the cylinders in the engine during some operating modes, such as steady-speed freeway driving.[75]
- **Improved lubricating oil** that reduces friction and cuts global warming pollution.[76]

Many of these technologies are already in use in select vehicles or specialty applications.

A recent study by the Northeast States Center for a Clean Air Future (NESCCAF) quantified the potential global warming pollution reductions that would be possible using these and other advanced technologies. NESCCAF looked at different combinations of technologies applied to five different classes of vehicles, and concluded that emissions could be reduced by 14 to 54 percent by 2015.[77] For the largest cars, emissions reductions of 14 to 30 percent could actually *save* consumers up to $1,900 over the life of the vehicle by lowering operating expenses.

Manufacturing Experience and Consumer Acceptance

To date, at least 13 automakers have manufactured conventional vehicles certified for PZEV credit under the Clean Cars program.[78] (See Table 3.) Most vehicles that have been certified as PZEVs thus far use a combination of technologies to achieve toxic and smog-forming emission reductions. Vehicles certified as AT-PZEVs include advanced technologies that may help lower global warming pollution.

While many of the various technologies listed in the previous section have been used for several years, it has only been recently 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 that sales of 2003 model year PZEVs would reach 140,000 vehicles.[80] Because some 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 toxic and smog-precursor emission improvements attained by vehicles meeting the PZEV standard have

Table 3. Certified PZEV Credit Model Year 2005 Vehicles[79]

Manufacturer and Model	Certification	Fuel
BMW 325Ci coupe	PZEV	Gasoline
BMW 325i (sedan, wagon)	PZEV	Gasoline
Chrysler Dodge Stratus sedan	PZEV	Gasoline
Chrysler Sebring sedan	PZEV	Gasoline
Ford Escape HEV	AT-PZEV	Gasoline
Ford Focus ZTW wagon	PZEV	Gasoline
Ford Focus ZX3	PZEV	Gasoline
Ford Focus ZX4 sedan	PZEV	Gasoline
Ford Focus ZX4 ST	PZEV	Gasoline
Ford Focus ZX5	PZEV	Gasoline
Honda Accord sedan (LX, EX)	PZEV	Gasoline
Honda Civic GX (w/CVT transmission)	AT-PZEV	Natural Gas
Honda Civic Hybrid	AT-PZEV	Gasoline
Hyundai Elantra	PZEV	Gasoline
Kia Spectra	PZEV	Gasoline
Mazda 3	PZEV	Gasoline
Mazda 6	PZEV	Gasoline
Mitsubishi Galant	PZEV	Gasoline
Nissan Altima (2.5, 2.5S)	PZEV	Gasoline
Nissan Sentra (1.8, 1.8S)	PZEV	Gasoline
Subaru Legacy (2.5i, 2.5i-Ltd)	PZEV	Gasoline
Subaru Legacy wagon (2.5i, 2.5i-Ltd)	PZEV	Gasoline
Subaru Outback wagon (2.5i, 2.5i-Ltd)	PZEV	Gasoline
Toyota Camry	PZEV	Gasoline
Toyota Prius	AT-PZEV	Gasoline
Volkswagon Jetta	PZEV	Gasoline
Volvo S60	PZEV	Gasoline
Volvo V70	PZEV	Gasoline
Volvo S40	PZEV	Gasoline
Volvo V50	PZEV	Gasoline

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.[81] The validity of this estimate is supported by the pricing decisions of several manufacturers. Ford sells the PZEV version of the Focus for $115 more in states that have not adopted California's Clean Cars standards.[82]

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 the Clean Cars program.[83] For the most part, both American and foreign automakers have limited distribution of PZEVs to states that have adopted the Clean Cars program.[84]

With regard to reducing global warming pollution, many advanced technologies are making slow but steady progress into the marketplace. Manufacturers have used these technologies to increase vehicle power in the past several decades, not to reduce greenhouse gas emissions. Direct-injection engines have been used for years in diesel vehicles and automakers are beginning to use them in gasoline vehicles. Honda, Audi, Nissan, BMW, and Saturn have included continuously variable transmissions in some models of their vehicles.[85] 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.[86]

Future Prospects

As the newest 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 the Clean Cars program 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—has helped push emission-control technology forward, far less impetus exists for the deployment of technologies to reduce global warming pollution in conventional vehicles.

The one existing program that has succeeded in reducing greenhouse gas emissions from conventional automobiles is the federal Corporate Average Fuel Economy (CAFE) program. The CAFE program was adopted in 1975 as an energy conservation measure that has had the additional benefit of reducing global warming pollution from automobiles. 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.[87]

However, the momentum toward more fuel efficient cars—ones that also produce less greenhouse gas pollution—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.[88] These vehicles are subject to less stringent fuel economy standards and thus have 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.[89]

The federal government recently approved a modest increase in CAFE standards for light trucks—from 20.7 MPG in 2003 to 22.2 MPG in the 2007 model year.[90] While this increase will spur the introduction of some technologies over the next several years that will reduce global warming pollution, much greater gains are technologically and economically feasible.

Washington's ability to improve the fuel economy of vehicles sold in the state is constrained by federal law. Washington does, however, have the power to adopt the Clean Car standards—which include the LEV II program and vehicle global warming pollution standards—that can reduce vehicle emissions of toxic pollutants, smog-forming chemicals and global warming gases.

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: NREL/DOE

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 November 2004, CNG prices per gasoline-gallon-equivalent ranged from $1.03 to $1.80 compared to gasoline prices of $1.87 to $2.23 per gallon.[91] 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 of toxics and smog precursors and reduced emissions of global warming gases. Five models of trucks and vans—all made by Ford—are certified as SULEVs under the Clean Cars program, while the Honda Civic GX has been certified to receive advanced technology partial zero-emission vehicle (AT-PZEV) credit as a result of its low tailpipe and evaporative emissions and emission-system warranty.[92]

In an effort to encourage the use of alternative fuel vehicles, Washington exempts CNG vehicles from emission control inspections.[93]

The biggest challenge to the success of natural gas vehicles has been the lack of available refueling facilities. As of January 2005, Washington had only 21 CNG refueling sites and no refueling sites for LNG vehicles. Making matters worse for private owners of natural gas vehicles is the fact that only two of Washington's CNG refueling sites are classified as public refueling stations; the other 19 sites service government vehicles and large privately-owned fleets of vehicles.[94]

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.[95] 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 fall 2004, FuelMaker Corporation—in partnership with American Honda—announced a prototype of the first home CNG-vehicle fueling system, which it projected would be available for sale in spring 2005. The cost of the appliance—which takes its natural gas from a home's gas line and can refuel a vehicle overnight—is anticipated to be approximately $2,000.[96]

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.[97]

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 144,000 in 2004.[98] (See Figure 5.) In addition, there are an estimated 3,000 LNG vehicles in use today, compared to just 300 in 1993.

Many major automakers—including Ford, DaimlerChrysler, General Motors, Honda and Toyota—manufacture CNG versions of their conventional vehicles, mostly for vehicle fleets. (See Table 4.) Only Honda, however, appears to be

Figure 5. Compressed Natural Gas Vehicles In Use, U.S.[99]

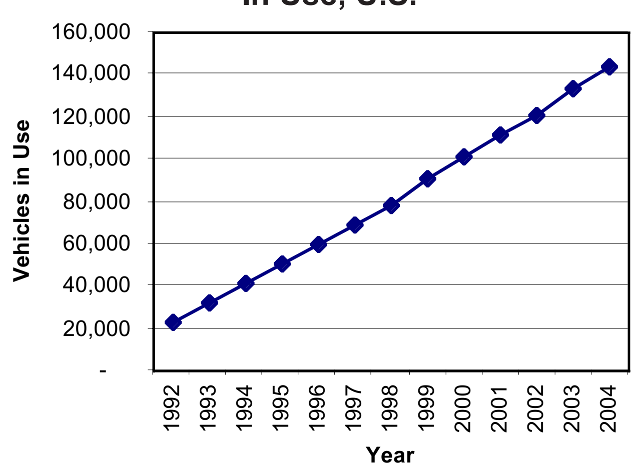


Table 4. Model Year 2005 Compressed Natural Gas Vehicles[100]

Manufacturer	Model	Type	CA Emission Rating
Honda	Civic GX	Car	AT-PZEV
Chevrolet	Silverado C2500 HD	MDV	SULEV
Chevrolet	Silverado K2500 HD	MDV	SULEV
Chevrolet	Express G1500/2500	MDV	LEV
Chevrolet	Express G3500	MDV	SULEV
Chevrolet	Van G3500	MDV	SULEV
GMC	Sierra C2500	MDV	SULEV
GMC	Sierra K2300	MDV	SULEV
GMC	Savana G 1500/2500	MDV	SULEV
GMC	Savana G3500 (cargo and passenger)	MDV	SULEV

MDV = Medium-duty vehicle
AT-PZEV = Advanced technology partial zero-emission vehicle
SULEV = Super low-emission vehicle
LEV = Low-emission vehicle

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.[101]

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.[102] Though demand fell by 5 percent from 2002 to 2003, this drop is likely temporary as the accelerating switch to natural gas for electricity generation will lead to a dramatic increase in overall consumption over the next several decades.[103] 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.[104]

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.[105]

Natural gas prices have risen dramatically in recent years. In the past two years alone, wholesale prices have increased by 50 percent.[106]

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.

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.

Photo: Electric Vehicle Association of Canada

Toyota's RAV4-EV is one of several battery-electric vehicles that have been manufactured by major automakers 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.[107]

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.[108]

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.[109]

However, the issuance of a judicial injunction against the enforcement of the Clean Cars program in California in 2002—and the subsequent delay in the implementation of the 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. DaimlerChrysler'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.[110] 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.[111]

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.[112] Additionally, automakers failed to offer types of vehicles that appealed to people interested in buying an EV.[113] 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.[114]

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. In addition, all are bulky, limiting cargo space in the vehicle. Yet many of these problems also confront vehicle technologies current in development, such as hydrogen vehicles.

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.[115] Argonne National Laboratory projects that by 2020, an EV equipped with a lithium-ion battery could have a range of 225 miles.[116] Though 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.

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.

Plug-in hybrids have significantly reduced global warming emissions compared to hybrid-electric and conventional gasoline-powered vehicles. One study estimates that, through all stages of use, plug-in hybrids emit 60 percent less carbon dioxide than a conventional vehicle.[117]

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.[118]

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.[119]

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.[120] 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.[121]

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. (Fuel cell vehicles may also contain a battery to help the vehicle run more efficiently, in effect creating a hybrid-fuel cell vehicle.)

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, biomass, 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 free of toxic and global warming emissions. 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. Nonetheless, a trade-off remains between using renewably generated electricity to create hydrogen for transportation and using that electricity to retire dirty power plants.

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.[122] 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."[123]

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 in metal hydrides—that can hold 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.[124]

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, curb global warming pollution, or reduce 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 toxic and greenhouse gas pollution continues to exist. Further, leakage of hydrogen into the atmosphere from vehicles, pipelines, and fueling stations could affect the climate by allowing methane to remain in the atmosphere longer and altering cloud formation.[125]

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.[126] 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.[127] Meanwhile, the first hydrogen filling stations in the U.S. have been built in California, Arizona and Nevada.[128]

Automakers, government researchers and 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 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.[129]

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 the Clean Cars program. 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 Clean Cars Program

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

The most effective way to promote the sale of advanced-technology vehicles in the state would be adoption of the Clean Cars program, which includes the LEV II program and vehicle global warming pollution standards.

The Low-Emission Vehicle 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 1990, 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 first Low Emission Vehicle (LEV) program in the early 1990s. More recently, New Jersey, Rhode Island and Connecticut have moved to adopt the current version of the program, known as LEV II.

As the initial 1998 compliance date for the original LEV program crept nearer, California moved to add flexibility. In addition to other requirements, the original 1990 program required that 2 percent of automobiles sold beginning in 1998 be zero-emission vehicles (ZEVs), with the percentage increasing to 5 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 zero-emission vehicle 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.[130]

In 1998, CARB amended the program again, allowing manufacturers to receive 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 ZEV 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 II program in that state for the 2003 and 2004 model years.[131] 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 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 (which are heavily dependent on batteries) in the near term, while boosting requirements for the sale of hybrid-electric or other advanced-technology cars.

How It Works

The LEV II program technically requires that 10 percent of all vehicles sold in the state be zero-emission vehicles beginning in model year 2005. In actuality, though, percentages of vehicles called for under the LEV II program 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

The LEV II program 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 in states that have adopted the LEV II program between model years 2005 and 2008. The fuel-cell vehicle requirement would increase to 2,500 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.[132] Prior to enforcement of the pure ZEV sales requirements for model year 2009, CARB will undertake a review of fuel-cell vehicle technology to ensure that it is feasible and available for the general market. If the review board determines that fuel-cell vehicles are not yet marketable, the sale requirement will be delayed.[133]

The LEV II program would not require the sale of any additional fuel-cell vehicles in Washington until model year 2012, assuming the CARB review board determines fuel-cell vehicle technology is ready for the consumer market. However, adopting the program in Washington would allow automakers to claim credit for fuel-cell vehicles placed in Washington, increasing the likelihood that a limited number of fuel-cell vehicles would find their way onto the state's highways. In addition, beginning in model year 2012, automakers would be required to sell a thousand fuel-cell vehicles per year in Washington.[134] Even then, the number of pure ZEVs required for sale in Washington would be small, representing less than one percent of new car and light truck sales until model year 2018.[135]

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. Manufacturers also can earn 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.[136]

Partial ZEV (PZEV) Credits

The law allows manufacturers to meet up to three-fifths of the 10 percent ZEV requirement by marketing ultra-clean conventional, gasoline-powered cars. To receive partial ZEV, or PZEV, credit, vehicles must meet 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.[137] 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.[138] 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 two-fifths 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.

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.[139]

Currently, the Toyota Prius, the Honda Civic hybrid, and the Ford Escape are the only gasoline-powered hybrid vehicles to meet AT-PZEV standards. Honda's natural-gas powered Civic GX also meets AT-PZEV standards.

Other Features

Under the LEV II program, 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, the LEV II program 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 program's requirement.

Another important change adopted by CARB in 2001 is a gradual ratcheting up of the ZEV requirement from 11 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.

Assuming that manufacturers choose to satisfy the ZEV requirements of the LEV II program with a mix of PZEVs and AT-PZEVs and that Washington adopts the program beginning in model year 2009, carmakers would sell 12,000 AT-PZEVs and 52,400 PZEVs in the first year of the program. (See Table 6.) Provided that CARB concludes that ZEV technology is ready for the consumer market, in model year 2012, manufacturers would have to sell 1,000 pure ZEVs in Washington.

Table 5. LEV II Program ZEV Percentage Requirement[140]

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

Table 6. Estimated Sales in Washington under the LEV II Program[141]

Model Year	PZEV	AT-PZEV	ZEV
2009	52,400	12,000	0
2010	57,600	13,200	0
2011	62,800	14,500	0
2012	68,300	16,400	1,000
2013	68,300	16,400	1,000
2014	68,300	16,400	1,000
2015	70,300	23,300	1,900

Adoption of the LEV II program, therefore, would result in the sale of tens of thousands of vehicles in Washington 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 "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 reduces emissions unless required to by law—despite consumers' stated desire for more environmentally benign vehicles. The LEV II program gives consumers access to emission control technologies and promotes further technological development that will result in even cleaner cars in the future.

The program achieves four important goals in hastening this technological shift, while at the same time reducing air pollution.

Ensuring a Supply of Clean Vehicles

As noted above, consumer reaction to many types of advanced-technology vehicles has been positive. Yet, in Washington, 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 Massachusetts and New York that have already adopted the LEV II program, but there is no guarantee of their availability in Washington. Hybrid vehicles are also in short supply and the available choices of vehicle types are extremely limited.

The LEV II program 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, the LEV II program 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 program reduced the need for new refueling infrastructure for pure ZEV 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, the LEV II program 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 II 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 program has thus far been a rousing success. For example, prior to California's 1990 adoption of the original 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 ZEV requirement, the amount of patent activity skyrocketed: between 1992 and 1998, the number of EV-related patents increased by about 20 patents per year.[142] More recently, a similar trend has been documented for fuel-cell vehicle-related patents.[143]

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 II program not been in existence, it is doubtful that these technologies would be as advanced as they are today.

The recent changes to the ZEV requirement 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, the LEV II program 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.

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 Washington is beyond the scope of this report, but analysis conducted for Massachusetts, New York, and Vermont suggests Washington would have much to gain from adoption of the LEV II program.

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 the LEV II program versus the Tier 2 federal standards that would otherwise be in effect. While both programs reduce air pollution, NESCAUM's analysis found that the LEV II program 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 additional 3 percent compared to Tier 2.[144]

Similar percentage emissions savings would apply to any state that adopted the LEV II program.[145] Thus it is clear that adoption of this program 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 the program would set Washington on a path to enjoy the benefits of the next generation of cleaner vehicles as soon as they become available.

Cost

Critics of the program 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 the LEV II program and ZEV requirement and the demonstrated market success of hybrids, any such concerns about cost are no longer valid. The adoption of the LEV II program in Washington 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 compliance with sales goals—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 the LEV II program represent 26 percent of the national car and light truck market.[146] This means that manufacturers already have invested in research and production facilities.

Table 7. Estimated Cost of Compliance with LEV II's ZEV Requirement in Washington (in millions)

Model Year	PZEV	AT-PZEV	ZEV	Total
2009	$5.2	$14.3	$0.0	$19.5
2010	$5.8	$15.9	$0.0	$21.7
2011	$6.3	$17.4	$0.0	$23.7
2012	$6.8	$11.5	$8.9	$27.2
2013	$6.8	$11.5	$8.9	$27.2
2014	$6.8	$11.5	$8.9	$27.2
2015	$7.0	$16.3	$17.9	$41.2

Cost to Manufacturers

Assuming the requirements for vehicle sales in Washington presented above, and CARB's estimates for the cost of complying with those requirements using clean conventional cars and hybrids, adoption of the LEV II program's ZEV requirement in Washington would cost automakers approximately $19.5 million in model year 2009 in technological improvements.

Though incremental costs fall over time, the total cost would rise to $41.2 million in model year 2015 due to higher volume sales and the inclusion of a pure ZEV sales requirement.[147] (See Table 7.) Before requiring the sale of pure ZEVs, CARB will review the available technology to confirm that it is adequately advanced to be sold to consumers and to begin creating a stronger market for ZEVs.

These costs translate to an additional $304 per ZEV-compliant model year 2009 vehicle sold or an average of $85 per light-duty vehicle sold in Washington.

To further put these figures in perspective, the estimated cost to automakers in 2008 (model year 2009) represents 0.0025 percent of the gross sales of the six major manufacturers in 2003. And $19.5 million is a minor expense compared to the nearly $19 billion in profits those automakers earned in 2003.[148]

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

First, vehicles sold under the LEV II program can be used by automakers toward compliance with other federal and state regulatory requirements. Should Washington adopt the LEV II program, the hybrid vehicles manufacturers sell under the program—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 such as hybrids 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. Thus the LEV II program 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.[149]

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 the LEV II program, Washington consumers will likely see only a modest 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.[150] In California, for example, Toyota sells the same model Camry in both PZEV and non-PZEV versions, with no difference in price. Ford does not charge more for the PZEV version of the Focus in states that have adopted the LEV II program; in other states it charges an additional $115 to consumers who want to purchase the PZEV version, which has better performance.[151] Honda markets a PZEV and non-PZEV version of the Accord, with a price differential of only $150.[152] 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 cost more 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.[153]

Whether the price that manufacturers charge for hybrid vehicles drops will depend in part on how much manufacturing costs fall but also on manufacturers' ability to meet consumer demand. If consumer demand for hybrids is strong, manufacturers will be able to charge a premium for the vehicles and prices may not fall as far as would be indicated by the cost of the technology alone.

Government incentives for the purchase of advanced-technology vehicles can help offset the cost of purchasing hybrid and alternative fuel vehicles. Federal incentives include tax deductions of $2,000 for the purchase of many hybrid and clean fuel vehicles. However, this incentive is scheduled to drop to $500 in 2006 and to end entirely in 2007.[154] In addition, a tax deduction of up to $100,000 per location is available for installation of refueling or recharging stations by businesses.[155] 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 2007.[156]

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 (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.[157] 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.

Vehicle Global Warming Pollution Standards

History

Continuing its tradition of groundbreaking legislation to reduce pollution from motor vehicles, in 2002 California expanded the Clean Cars program and adopted the nation's first law to control carbon dioxide emissions from automobiles. On September 24, 2004, the California Air Resources Board (CARB), the division of the California Environmental Protection Agency that oversees air quality, adopted rules for implementation of the global warming pollution standards. The California Legislature will review the standards in 2005 before they can take effect. Assuming the Legislature does not revise the program, beginning in model year 2009, car manufacturers will have to adhere to fleet-average emission limits for carbon dioxide.

How It Works

The California legislation requires CARB to propose limits that "achieve the maximum feasible and cost effective reduction of greenhouse gas emissions from motor vehicles." Limits on vehicle travel, new gasoline or vehicle taxes, or limitations on ownership of SUVs or other light trucks cannot be imposed to attain the new standards.[158]

The global warming pollution standards are based on the average emissions of all vehicles sold by a manufacturer in each model year. How much reduction an individual manufacturer needs to achieve will depend on that maker's starting point. Emissions from cars and smaller light-duty trucks will be calculated as one unit, with emissions from larger light-duty vehicles calculated as another group.

The standards will take effect with model year 2009. Carmakers may earn early compliance credits to offset the program's requirements by reducing the greenhouse gas pollution of the cars they sell in model years prior to 2009. If, for example, a manufacturer's vehicles sold in model year 2007 have a grams-per-mile fleet average lower than that required by the program in 2012 (the benchmark year), the maker earns credits that can be used in the first few years of the program.[159]

Benefits

Like the LEV II program, the vehicle global warming pollution standards will help encourage automakers to improve on existing advanced technologies and invent new ones. Many of the technologies that reduce global warming pollution are already in use in select vehicles. By establishing a global warming pollution reduction goal that carmakers must meet, the program will lead to widespread use of these technologies and to cleaner vehicles. As manufacturers find ways to improve upon existing technologies, the cost of those products should drop over time, reducing the cost—or increasing the savings—of cutting global warming pollution.

Environmental Benefits

CARB's August 2004 proposal, a version close to the one finally sent to the California Legislature for review, estimated that near-term (2009 to 2012) technologies could reduce average global warming pollution from cars by 25 percent and from light trucks by 18 percent. Over the medium term (2013 to 2016), cost-effective reductions of 34 percent for cars and 25 percent for light-trucks are feasible.[160]

Assuming that the August 2004 version of the global warming pollution standards is adopted as proposed—and that Washington would implement those standards as part of the Clean Cars program beginning with the 2009 model year—the reductions in global warming pollution that would result would be significant.

Costs

One guideline of the vehicle global warming pollution standards is that any required changes not cost consumers any additional money over the life of the vehicle. In other words, the technologies added to a car to reduce its greenhouse gas emissions must cost less than the amount consumers will save in operating costs.

The technological changes needed to achieve these reductions (such as five and six-speed automatic transmissions and improved electrical systems) will likely result in modest increases in vehicle costs that would be more than recouped over time by consumers in the form of reduced fuel expenses. CARB projects that cars attaining the 34 percent reduction in global warming pollution required by 2016 would cost approximately $1,115 more for consumers to purchase, while light trucks achieving the required 25 percent reduction would cost about $1,341 more.[161]

However, the agency also estimates that the rules will significantly reduce operating costs for new vehicles—particularly for fuel. By subtracting operating cost savings from the projected additional monthly payment associated with purchasing vehicles that comply with the standard, CARB projects that, upon full phase-in, consumers will save $3 to $7 every month as a result of the standards. CARB also projects that the net impact of the standards to the state's economy will be positive, suggesting that Washington could save money while at the same time reducing its overall emissions of global warming pollution.[162]

Policy Recommendation

Adopt the Clean Cars Program

Adoption of the Clean Cars program would be beneficial public policy for Washington. The program would provide public health benefits by reducing toxic, smog-forming, and global warming pollution from vehicles. The Clean Cars program would enhance the state's energy security, and stimulate research and development of clean car technologies. It is a viable public policy, given technological advances in clean car technologies over the past decade and consumer demand for clean vehicles. Furthermore, the program would save money for consumers over the life of their automobile.

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.

CO_2 – Carbon dioxide.

EV – Battery-electric vehicle.

LEV II – Low-Emission Vehicle II program, a component of the Clean Cars program. Includes stringent limits on emissions from light- and medium-duty vehicles and the LEV requirement.

LNG – Liquid natural gas.

MTCO2E – Million tons of carbon dioxide 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 category in the Clean Cars program and a prerequisite for qualification for PZEV credit.

ULEV – Ultra-low-emission vehicle; the third-cleanest emission category under the Clean Cars program.

VOC – Volatile organic compounds.

ZEV – Zero-emission vehicle.

METHODOLOGY

Percentages of vehicles meeting PZEV, AT-PZEV and ZEV criteria were estimated in the following manner:

- Light-duty vehicle sales in Washington for each category (cars and light trucks) were estimated based on year 2003 new vehicle registration figures from Alliance of Automobile Manufacturers, *Light Truck Country*, downloaded from autoalliance.org/archives/000141.html, 12 January 2005, with the light truck category divided into heavy and light light-duty trucks using EPA fleet composition estimates as described above. These figures were then multiplied by the percentage of sales subject to the Clean Cars program for each year.
- This number was multiplied by 0.9 to account for the six-year time lag in calculating the sales base subject to the Clean Cars program. (For example, a manufacturer's requirements in the 2009 through 2011 model years are based on percentages of sales during model years 2003 through 2005.)
- Where necessary, these values were multiplied by the percentage of vehicles supplied by major manufacturers versus all manufacturers as calculated from Ward's Communications, *2003 Ward's Automotive Yearbook*, 233. (Non-major manufacturers may comply with the entire Clean Cars program requirement by supplying PZEVs.)
- This value was then multiplied by the percentage sales requirement to arrive at the number of Clean Cars program credits that would need to be accumulated in each model year.
- The credit requirement was divided by the number of credits received by each vehicle supplied as described in California Environmental Protection Agency, Air Resources Board, *Final Regulation Order: The 2003 Amendments to the California Zero Emission Vehicle Regulation*, 9 January 2004.
- The resulting number of vehicles was then divided by total light-duty vehicle sales to arrive at the percentage of sales required of each vehicle type.
- No pure ZEVs were assumed to be required for sale in Washington until the 2012 model year. For the 2012 through 2017 model years, in which the pure ZEV requirement is based on a specific number of California sales, we divided the annual pure ZEV requirement in the California regulations by the number of new vehicles registered in California in 2001 per Ward's Communications, *2002 Ward's Automotive Yearbook*, 272. We assumed that the same percentage would apply to vehicle sales in Washington.

It was assumed that manufacturers would comply with ZEV and AT-PZEV requirements through the sale of fuel-cell and hybrid passenger cars.

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162. Assuming gasoline costs $1.74 per gallon. California Environmental Protection Agency, Air Resources Board, *Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles*, 6 August 2004; California Environmental Protection Agency, Air Resources Board, *Addendum Presenting and Describing Revisions to: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles,* 10 September 2004.