READY TO ROLL

The Benefits of Today's Advanced-Technology Vehicles for North Carolina

Tony Dutzik
Elizabeth Ouzts

NCPIRG Education Fund

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EXECUTIVE SUMMARY

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

Policies such as the Zero-Emission Vehicle program (part of the Low-Emission Vehicle II emission standards adopted by California, Massachusetts, New York and other states) can help bring increased numbers of advanced-technology vehicles to North Carolina.

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

- During the summer of 2002, air pollution monitors in North Carolina registered 612 exceedences of EPA health standards for smog on 51 separate days. Light-duty vehicles such as cars, pick-up trucks, minivans and sport utility vehicles (SUVs) are responsible for about one-fifth of all emissions of nitrogen oxides and one-quarter of all emissions of volatile organic compounds (VOCs) to the air nationwide. Nitrogen oxides and VOCs are the chemical components of smog.
- In 1996, concentrations of soot and air toxics in North Carolina's air were sufficient to pose a statewide average cancer risk of one new case for approximately every 3,200 residents – well above the EPA's one-in-a-million cancer risk benchmark for air toxics. Mobile sources, including cars and trucks, are responsible for about 41 percent of all air toxics emissions by weight nationwide.
- The use of personal cars and trucks was responsible for about 23 percent of North Carolina's 1990 emissions of carbon dioxide, which causes global warming. Global warming poses severe potential threats to coastal and forest ecosystems and public health in the state.
- North Carolina's overreliance on petroleum for transportation leaves the state susceptible to 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 smog-forming pollutants and air toxics from North Carolina cars and light trucks. The current generation of hybrid-electric vehicles – such as the Toyota Prius and Honda Civic – are approximately 90 percent cleaner than the average vehicle on sale in North Carolina today. Clean conventional vehicles with state-of-the-art emission-control technology are now being manufactured that attain similar pollution reductions.
- Advanced-technology vehicles can also reduce North Carolina's emissions of greenhouse gases, which cause global warming. Vehicles that take advantage of the benefits of hybrid-electric technology can produce about half as much global warming-inducing carbon dioxide per mile as conventional vehicles.
- Many advanced-technology vehicles also enhance North Carolina's energy security by improving fuel efficiency or using alternative fuels such as natural gas, electric power or hydrogen.

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

- **Hybrid-electric vehicles:** More than 65,000 hybrid-electric vehicles have been sold in the U.S. since 1999. As many as 60 percent of potential vehicle buyers in a recent survey stated that they would consider buying a hybrid, yet only three models of hybrid vehicles are currently available to North Carolina consumers.
- **Natural gas vehicles:** More than 120,000 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. Lack of refueling opportunities has hindered the further spread of these vehicles, and limitations in the supply of natural gas make them unsuitable as a long-term alternative.
- **Clean conventional vehicles:** Seven automakers now manufacture vehicles that meet California's rigorous partial Zero-Emission Vehicle (PZEV) emission standards. However, most of these vehicles have only been made available to consumers in states that have adopted Zero-Emission Vehicle programs.
- **Battery-electric vehicles:** Automakers have sold more than 10,000 zero-emission battery-electric vehicles to consumers in California and other states over the last decade. However, no major automaker is currently selling battery-electric vehicles to consumers.
- Other types of vehicles – such as "plug-in" hybrids and hydrogen fuel-cell vehicles – also show the potential for significant environmental benefits, but will require further research and development before they become commercially feasible.

Adopting the Zero-Emission Vehicle (ZEV) program would put hundreds of thousands of advanced-technology vehicles on North Carolina's roads by the end of the decade, at minimal cost to automakers and potential net benefits to consumers.

- The ZEV program would require automakers to sell approximately 107,000 hybrid-electric vehicles and 587,000 clean conventional vehicles in North Carolina between 2007 and 2011, with the numbers increasing over time.
- Installing the technology to meet these targets would cost automakers approximately $26 million in 2007, increasing to $49 million in 2011. The incremental cost of the program in 2007 represents about 0.14 percent of sales by North Carolina new-car dealers in 2001 and 0.004 percent of the gross revenue of the six major automakers. Offsetting financial benefits stemming 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 ZEV-compliant vehicles will reduce these costs further.
- Consumers are unlikely to be negatively affected by the ZEV program. Most automakers have chosen not to pass on the additional cost of conforming with PZEV emission standards. Should the cost of hybrid-electric vehicles decrease (as is anticipated), and gasoline prices rise, many consumers will see a net financial benefit from purchasing more efficient hybrid-electric vehicles.

Adoption of the Low-Emission Vehicle II and Zero-Emission Vehicle programs is essential to getting clean, advanced-technology vehicles onto North Carolina's roads.

- The ZEV program would ensure a consistent supply of clean vehicles for North

Carolina 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 a ZEV requirement in North Carolina are attainable, and achieving them would be beneficial to the state. To ensure successful implementation of the program, the state should take a leadership role in coordinating the expansion of alternative-fuel infrastructure and educating the public about clean cars, and work to secure resources to support those efforts.

INTRODUCTION

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

Hybrid-electric vehicles – virtually unknown ten years ago – have begun to make their way onto North Carolina's highways, offering dramatically increased gasoline mileage and lower emissions of smog-forming pollutants. Natural gas and other alternative-fuel vehicles have become commonplace in government and private fleets. Zero-emission battery-electric vehicles have overcome technical hurdles to provide greater range and performance at lower cost. Conventional gasoline vehicles are now being made that are virtually free of smog-forming and toxic emissions – a far cry from ten years ago.

Small numbers of hydrogen-powered fuel-cell vehicles – once an engineering fantasy – are now on the roads in demonstration projects, with more to come soon. And new vehicle types – such as "plug-in" hybrids that fuse the benefits of hybrid-electric and battery-electric vehicles – are now on the drawing board.

The promise of a new generation of cleaner, more environmentally benign cars has never been brighter. Yet, the vast majority of vehicles sold in North Carolina today do not incorporate the latest in advanced technology. Even worse, many of the most promising advanced-technology vehicles – battery-electric vehicles and ultra-clean conventional vehicles, for example – cannot be purchased from major automakers anywhere in North Carolina.

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 at its lowest point in the last two decades.[1] Smog – largely caused by motor vehicles – continues to threaten the health of hundreds of millions of Americans each summer. And the nation remains vulnerable to price spikes due to the inefficient use of petroleum as a transportation fuel.

Getting advanced-technology vehicles onto North Carolina's roads will require more than just financial incentives. For years, buyers of battery-electric and alternative-fuel vehicles have been eligible for tax breaks and other benefits. Yet, for the most part, the vehicles have simply not been made available to the general public. Even hybrid-electric vehicles – now six years removed from their successful introduction in Japan – are still only available from two foreign automakers and only in a limited variety of models. It will be another year before a U.S. automaker offers its first hybrid to the general public.

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

Seeing the value of the ZEV program's unique approach, three northeastern states – New York, Massachusetts and Vermont – have adopted the program for themselves. Other states are now considering whether to follow suit.

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

North Carolina cannot afford to let this revolution pass us by.

WHY WE NEED ADVANCED-TECHNOLOGY VEHICLES

The internal combustion engine has proven to be one of the defining technologies of the 20th century, providing mobility to millions at relatively low cost. However, our inefficient use of fossil fuels – particularly for transportation – has also led to a variety of negative impacts, including air pollution, the build-up of greenhouse gases in the atmosphere, and periodic price spikes and supply disruptions with the potential to wreak havoc on the economy. While pollution-control mechanisms for cars and trucks have reduced some of these impacts, others are innate to the process of burning fossil fuels in internal combustion engines to get ourselves from place to place. The development and introduction 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 and Honda Insight, use an on-board electric motor to assist in the propulsion of the vehicle, resulting in significantly greater fuel economy than conventional vehicles. Unlike battery-electric vehicles, hybrid-electric vehicles do not need to be recharged through a connection to the electric grid.
- **Clean conventional vehicles** – In recent years, automakers have begun to introduce conventional, gasoline-powered vehicles that are virtually free of smog-forming and toxic emissions. Other technological advances allow the production of vehicles with improved fuel economy, potentially reducing the emission of greenhouse gases to the atmosphere.
- **Dedicated natural gas vehicles** – Two types of natural gas are currenty used to power vehicles, liquid 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 only be operated 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 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. Hydrogen may be provided di-

rectly to the vehicle or be "reformed" on board from natural gas or other fossil fuels.

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

Air Quality

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

Large sections of North Carolina fail to meet federal health standards for ozone smog. Particulate "soot" and toxic air contaminants also pose severe threats to the health of thousands of North Carolina residents. With many North Carolina residents driving increasing distances in their cars, the threat posed by automotive air pollutants to public health is likely to increase.

Smog

During the summer of 2002, air pollution monitors in North Carolina registered 612 exceedences of EPA health standards for ground-level ozone – better known as smog – on 51 separate days, more than triple the number of exceedences registered in 2001.[2]

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, increased stroke mortality, asthma attacks, and recently to the onset of asthma itself.[3]

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 about one-fifth of all of NOx emissions and one-quarter of all emissions of VOCs to the air.[4]

Soot and Air Toxics

Particulate matter, or "soot," and airborne toxic chemicals also pose a significant health threat to North Carolina residents. In 1996, concentrations of soot and air toxics in North Carolina's air were sufficient to pose a statewide average cancer risk of one new case for approximately every 3,200 residents – well above the EPA's one-in-a-million cancer risk benchmark. Residents of all 100 North Carolina counties were exposed to levels of benzene and formaldehyde that exceeded the one-in-a-million cancer risk benchmark. In many counties, pollution from mobile sources (including cars, trucks and off-road equipment) accounted for significant portions of the added cancer risk.[5]

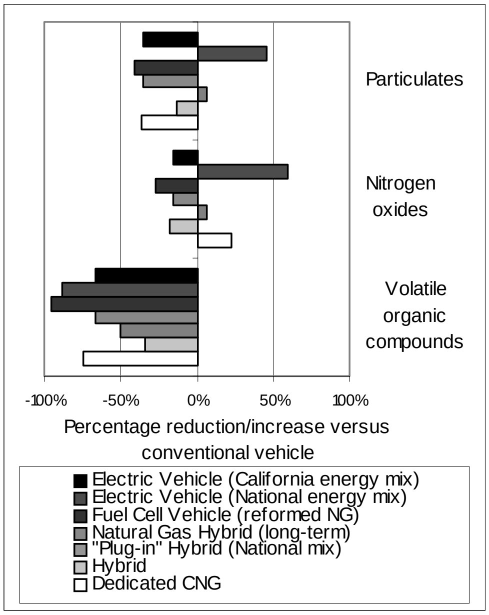
Light-duty vehicles are likely responsible for only a small portion of the state's soot emissions, with the on-road mobile source contribution to the soot problem largely coming from heavy-duty trucks. However, it is likely that light-duty vehicles make a significant contribution to the concentrations of toxic chemicals in our air that increase cancer risks for North Carolina residents. The EPA estimates that mobile sources, including cars and trucks, are responsible for about 41 percent of air toxics emissions by weight nationwide, with on-road vehicles responsible for about half that amount.[6]

How the Technologies Stack Up

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." Their analysis shows that the use of many advanced technologies can lead to significant reductions in air emissions versus conventional, internal combustion engine vehicles that operate on gasoline.

Fuel-cell and hybrid vehicles have significantly reduced per-mile fuel-cycle emissions

Fig. 1: Per-Mile Emissions of Advanced-Technology Vehicles



of particulate soot, nitrogen oxides and volatile organic compounds versus conventional gasoline-powered cars. The benefits of electric vehicles and "plug-in" hybrids are greatly dependent on the cleanliness of the fuel "mix" used to generate the electric power they use. As can be seen in Figure 1, electric and plug-in hybrid vehicles would provide greater environmental benefits to North Carolina if the state were to move toward a cleaner electricity mix such as California's. The significant reductions in volatile organic compound emissions from these and other advanced-technology vehicles, however, would reduce North Carolinians' exposure to many air toxics.

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

Global Warming

Carbon dioxide and other greenhouse gas pollutants pose serious threats to the health of North Carolina residents. Over the last century, the average annual temperature in Chapel Hill has increased by 1.2° F and precipitation has increased by up to 5% in some parts of the state. Should the concentration of greenhouse gases continue to increase over the next century, North Carolina could see a further 3°F increase in average temperature and a 15% increase in precipitation due to global warming.[7]

These changes could have a dramatic effect on the environment and our way of life. Potential impacts include increased heat-related deaths, transmission of malaria and other mosquito-borne diseases, more frequent toxic algae blooms in coastal waters, and alteration of forest and other ecosystems.[8] Rising temperatures could lead to longer and more severe smog seasons, further placing public health at risk.

North Carolina would also be susceptible to the impact of global warming-induced sea level rise. At Long Bay, southwest of Wilmington, the sea level is already rising at a rate of approximately 2 inches per century and could rise by as much as another foot by 2100.[9] Beach erosion, the loss of coastal wetlands, coastal flooding and property damage could all result – as could increased damage from hurricanes.

In 1990, North Carolina released approximately 135 million tons carbon dioxide equivalent (MTCDE) of greenhouse gases to the atmosphere. Of that amount, 42.8 MTCDE – or approximately 32 percent – came from the transportation sector, with 32.8 MTCDE, or 22.6 percent of the statewide total, coming from personal vehicles.[10] North Carolina's emissions of greenhouse gases were significant on the global scale. North Carolina's 1990 carbon dioxide emissions would have ranked the state 32nd among the countries of the world reporting their

Fig. 2: Per-Mile Carbon Dioxide Emissions of Advanced-Technology Vehicles

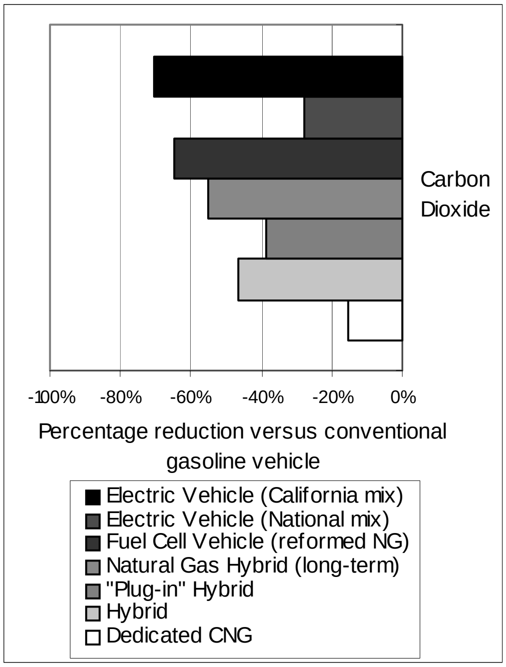
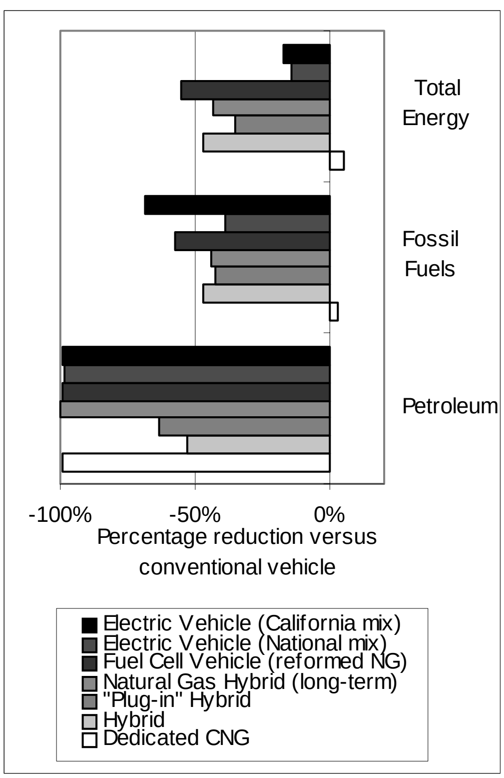


Fig. 3: Per-Mile Energy Use of Advanced-Technology Vehicles



emissions that year – just above Argentina and just below Venezuela.[11] Carbon dioxide emissions from the North Carolina transportation sector *alone* in 1990 would have ranked the state 54th among the nations of the world, between Kuwait and Singapore.[12]

No technology akin to the catalytic converter 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 is used to power the vehicle and b) the vehicle's efficiency in making use of fuel.

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

Energy Security

The nation's reliance on fossil fuels – particularly petroleum – to power our vehicles creates the potential for serious price and supply disruptions, as took place during the oil embargoes of the 1970s.

Such disruptions are even more likely to occur in the future, as readily accessible sources of oil are exhausted and supplies become stretched. 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.[13] 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.[14]

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

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

The Need for Immediate Action

The number of miles driven on North Carolina highways has more than doubled in the last two decades, from 41 billion miles in 1980 to 91 billion miles in 2001.[15] This trend is unlikely to be reversed soon. As a result, North Carolina will likely continue to face major negative public health, environmental and economic consequences due to automobile air pollution.

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

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

EVALUATING ADVANCED-TECHNOLOGY VEHICLES: LEV II AND ZEV STANDARDS

In 1990, California adopted the Low-Emission Vehicle (LEV) program, which set aggressive emission standards for automobiles. A key facet of the program was the Zero-Emission Vehicle (ZEV) requirement, which required automakers to sell increasing numbers of vehicles with no tailpipe emissions. The ZEV program has subsequently been modified to allow credit for vehicles with extremely low emissions and has been adopted – along with the LEV program and its successor, LEV II – by several northeastern states.

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

- Automobiles meeting super-low emission vehicle (**SULEV**) standards under the LEV II program release about 90 percent less smog-forming pollution than the average vehicle sold today.
- Vehicles that receive partial Zero-Emission Vehicle (**PZEV**) credit under the ZEV program 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 to fuel ZEVs often creates some pollution).

ADVANCED-TECHNOLOGY VEHICLES AVAILABLE TODAY

Hybrid-Electric Vehicles

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

By the 1990s, however, 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 with the introduction of 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.

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.

Photo: Electric Vehicle Association of Canada

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

A "full" hybrid vehicle – such as the Toyota Prius – includes four basic characteristics:

- The capability to shut off the conventional engine when the vehicle is stopped.
- The use of regenerative braking, which captures energy that would otherwise be lost when a vehicle slows down.
- Reduced engine size versus conventional vehicles.
- The capability to drive the vehicle using only electric power.[16]

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

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

In addition to mild and full hybrids, the Union of Concerned Scientists has defined another category – the "muscle hybrid" – for vehicles that take advantage of idle shut-off and regenerative braking technologies without downsizing the engine. In these vehicles, the hybrid system is used primarily not to bring about increased fuel economy, but to add power to the vehicle. For example, GM describes its forthcoming hybrid Silverado pick-up truck, which includes two 110-volt outlets, as a "portable generator on wheels."[17] The environmental benefits of this type of hybrid are minimal; the hybrid system in the Silverado, for example, boosts fuel economy by only 10 to 12 percent.

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

The first generation of hybrid-electric vehicles has demonstrated clear environmental advantages over conventional vehicles. The three hybrid-electric vehicles for sale in 2003 each achieved EPA-rated fuel economy of greater than 45 miles per gallon (MPG) – nearly 10 MPG greater than the nearest gasoline-powered vehicle.[18] In addition, the 2003 models of all three vehicles are certified as super-low emission vehicles (SULEVs) in California, meaning that their emissions are 90 percent cleaner than the average 2003 model year car.[19]

Manufacturing Experience

As noted above, Toyota was the first major auto company to introduce a hybrid to the consumer market in 1997 in Japan. In the years since, Toyota and Honda have expanded the availability of their hybrid vehicles in the United States. (See Table 1.)

Table 1: Model Year 2003 Hybrid-Electric Vehicles

Mfr.	Model	Type
Toyota	Prius	Full Hybrid
Honda	Civic	Mild Hybrid
Honda	Insight	Mild Hybrid

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, anticipates manufacturing 300,000 hybrids per year by 2005.[20]

Indeed, Toyota is preparing to market a second-generation hybrid system as part of its redesigned Prius, scheduled to arrive at dealerships this fall. Toyota reports that the vehicle will have more power and room and will boast improved fuel efficiency and reduced emissions even when compared to the original Prius.[21]

Three years after Japanese automakers introduced hybrids to the U.S., America's "Big Three" automakers still have yet to sell their first hybrid. However, American automakers are preparing to introduce their first hybrid models within the next couple of years.

General Motors – GM plans to offer "muscle hybrid" versions of its Sierra and Silverado trucks to fleet customers beginning in 2003 and retail customers in 2004.[22] In 2005, GM plans to introduce a full hybrid version of its Saturn VUE SUV that will get approximately 50 percent better gas mileage and will carry a super-low emission vehicle (SULEV) emission rating.[23] In January 2003, General Motors announced that it will include a variety of hybrid technologies in several vehicles between 2005 and 2007.[24]

Ford – Ford plans to market a full hybrid version of its Escape SUV to fleets beginning in 2003 and the general public in late summer 2004. The vehicle is projected to attain EPA-rated fuel economy of 35 to 40 MPG – an increase of more than 40 percent versus current Escape models.[25] The Escape would be the first SUV to take substantial advantage of hybrid technology.

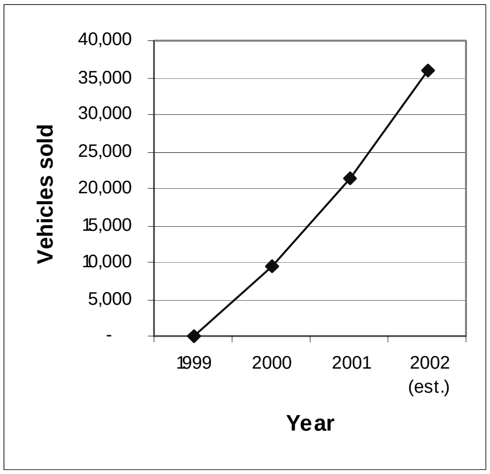
DaimlerChryler – DaimlerChrysler is expected to introduce a hybrid-electric version of its Dodge Ram pickup truck in 2005. DaimlerChrysler is also reported to be in discussions with Toyota about purchasing the company's hybrid system for use in a future hybrid-electric vehicle – a strategy similar to that being employed by Nissan.[26]

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.

Sales of hybrid vehicles have increased steadily since their introduction to the domestic market in 2000. As of the spring of

Fig. 4. Hybrid-Electric Vehicle Sales, U.S.[29]



2002, Toyota alone had sold more than 100,000 hybrids worldwide; nearly 40,000 of them in the U.S. In all, about 36,000 hybrids were sold in the U.S. in 2002, an increase of 73 percent from the previous year.[27] (See Fig. 4.) Should oil prices increase, demand for hybrids will likely follow; Toyota and Honda reported 30% increases in sales of hybrids in the weeks leading up to U.S. military intervention in Iraq in March 2003.[28]

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.

Indeed, the market potential of hybrids has only begun to be tapped. A recent J.D. Power and Associates report found that 60 percent of new vehicle buyers would consider buying a hybrid-electric vehicle. Nearly one-third of those said they would still buy a hybrid even if the added cost of the vehicle was not fully offset by fuel savings.[30] With major American automakers not planning to sell a hybrid to the general public until at least 2004, the prospect exists of the market failing to satisfy consumers' desire for hybrid-electric vehicles.

Cost

Hybrid-electric vehicles currently come at a cost premium to consumers, but the greater efficiency of the vehicles will also result in fuel cost savings. Both the Honda Civic hybrid and the Toyota Prius cost approximately $20,000, several thousand dollars more than comparable small cars. The California Air Resources Board (CARB) has estimated that the average incremental cost of a hybrid-electric vehicle will likely be approximately $3,300 between 2003 and 2005, $1,500 between 2006 and 2008, $1,200 between 2009 and 2011, and $700 thereafter.[31] However, hybrid-electric vehicles also typically get gas mileage far superior to conventional vehicles. A CARB staff analysis has found that a hybrid achieving 30% improved fuel economy would save its owner $1,000 in present value fuel costs over the lifetime of the vehicle, at an average fuel price of $1.75 per gallon.[32] In addition, purchasers of hybrids are currently eligible for a $2,000 federal tax deduction, further reducing the real cost of the vehicles to consumers.

As a result, consumers can still expect to pay more for the experience of driving a hybrid-electric vehicle for at least the next several years. But the price differential – already reduced by fuel savings and tax incentives – will continue to narrow as production volumes increase and hybrid-electric vehicle technology improves, placing advanced-technology vehicles within the economic reach of most North Carolina new-car buyers.

Future Prospects

While existing hybrid-electric vehicles have demonstrated significant gains in fuel economy and emission reductions, even greater gains 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 50-60 MPG by 2020.[33]

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

Natural Gas Vehicles

Vehicles powered by natural gas have distinct environmental advantages over those powered by gasoline. However, limitations in supplies of natural gas and volatile prices make natural gas unsuitable as a long-term or widescale replacement for gasoline-powered vehicles. In the short term, limited use of natural gas vehicles – particularly in hybrid form – can produce interim environmental benefits.

Vehicle Characteristics

Natural gas can be supplied to vehicles in one of two forms: compressed natural gas (CNG) or liquified 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 used in conventional gasoline vehicles. Vehicle performance is similar 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.

CNG vehicles have the potential for extremely low emissions. Seven models of trucks – all made by Ford and DaimlerChrysler – are certified as SULEVs by the state of California, while the Honda Civic GX has been certified to receive Partial Zero-Emission Vehicle (PZEV) credit as a result of its low tailpipe and evaporative emissions and emission-system warranty.[34]

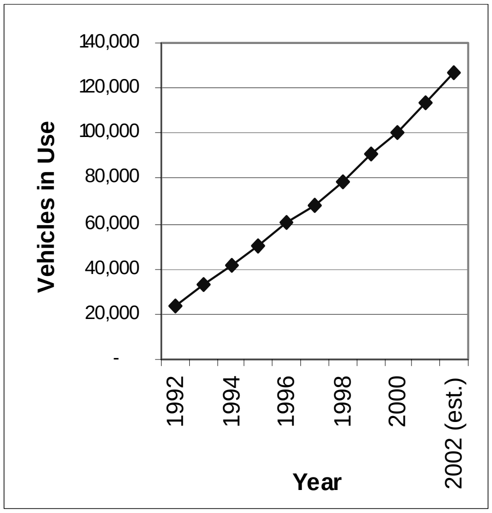
The biggest challenge to the success of natural gas vehicles has been the lack of available refueling facilities. As of March 2003, there were only 1,171 refueling sites for CNG vehicles nationwide, of which 11 were in North Carolina, and 44 sites for LNG vehicles, with none in North Carolina.[35] Of the 11 CNG fueling stations in the state, only 6 are open to the public, and the use of many of those public stations is subject to restrictions. The cost of building a CNG fueling station can be high. Fast-fill stations of mainstream size cost approximately $500,000 to construct, with public-access stations significantly more expensive than private-access ones.[36] The high costs of CNG refueling stations have generally limited construction to firms with CNG fleets that can refuel centrally and to natural gas suppliers.

However, the spread of home refueling systems could make CNG vehicles more attractive in the years to come. In 2002, FuelMaker Corp. – in partnership with American Honda – unveiled a prototype of the first home CNG-vehicle fueling system, which it projected would be available for sale in late 2003.[37] The cost of the appliance – which is about the size of a pay-phone booth, takes its natural gas from a home's gas line, and can refuel a vehicle overnight – is anticipated to be between $1,000 and $2,000.[38]

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.

Fig. 5. Compressed Natural Gas Vehicles In Use, U.S.



Manufacturing Experience

The number of natural gas vehicles on American roads has increased more than five-fold over the last decade. In 1992, only 23,000 CNG vehicles were on the road, compared to an estimated 126,000 in 2002.[39] (See Fig. 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. Only Honda, however, appears to be committed to a strategy of selling CNG vehicles to individual consumers. (See Table 2.)

Table 2: Model Year 2003 Compressed Natural Gas Vehicles[40]

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

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

Consumer Acceptance

While individual consumers have had limited experience with CNG vehicles, the vehicles have become increasingly popular with government and private fleets. As of 2000, there were approximately 390 CNG vehicles in use in North Carolina – less than one percent of the national total – but fleet drivers in many other states have had positive experiences with the vehicles.[41]

In a 1999 survey by the U.S. Department of Energy's National Renewable Energy Laboratory, 96 percent of fleet drivers of CNG vehicles for city governments 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.[42]

A 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.[43]

While tank size will likely remain an issue with CNG vehicles – particularly in small cars – there is little reason to believe that

CNG vehicles would not be positively received by consumers. This would especially be the case if public refueling opportunities are expanded, or if home refueling proves workable.

Cost

Natural gas vehicles are comparable in incremental cost to hybrid-electric vehicles. The natural-gas powered Honda Civic GX, for example, sells for about $20,000, about the same as the Civic Hybrid. General Motors' dedicated CNG vehicles for fleets come at a cost premium of about $6,000.[44]

CNG vehicle owners also generally benefit from lower fuel prices, providing a cost savings to owners. As of October 2002, CNG prices per gasoline-gallon-equivalent ranged from $0.76 to $1.40 compared to gasoline prices of $1.39 to $1.47 per gallon.[45] However, natural gas prices have historically been volatile and have varied significantly from region to region, making fuel cost savings difficult to predict. It is generally thought that natural gas prices will increase in the years to come due to growing demand from other sectors of the economy and potential shortages in domestic supply.

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 1981 to 2001, consumption of natural gas in the U.S. increased by 12 percent, but the accelerating switch to natural gas for electricity generation will likely lead to a dramatic increase in overall consumption over the next several decades.[46] The U.S. Energy Information Administration projects that natural gas consumption in the U.S. will increase by 54 percent between 2001 and 2025.[47]

At the same time, U.S. proved reserves of natural gas have declined by 11 percent since 1981. 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 9.2 years.[48]

Even if imports of natural gas increase significantly to fill the gap, 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 of natural gas vehicles – particularly in hybrid configurations that maximize their efficiency – can result in environmental benefits.

Clean Conventional Vehicles

Increasingly tight emission standards at the federal level and in California have driven significant reductions in emissions of smog-forming chemicals, air toxics, soot 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 in many urban areas.

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

Vehicle Characteristics

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

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

- **Faster-heating catalytic converters** to avoid emissions that take place while a car is heating up.
- **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.
- **Improved computerized control of the engine start-up sequence** to reduce "cold start" emissions.[49]
- **"Smog-eating" coatings on radiators** that convert ground-level ozone in ambient air into oxygen.[50]
- **Modified fuel tanks and lines** to control evaporative emissions.

In addition to implementing such new technologies, automakers must stand by their durability – placing 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 smog-forming and other harmful pollutants are not the only potential benefits of applying advanced technology to conventional vehicles. A host of technologies exist that could dramatically improve the fuel efficiency of today's vehicle fleets.

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

Even more conservative analysts note the potential for significant improvements in vehicle fuel economy. A 2002 National Research Council report found that automakers could cost-effectively boost the fuel economy of their fleets by 12 to 42 percent, with the greatest potential increases coming in the fuel economy of light trucks. In other words, the increase in price that consumers would face for these fuel economy improvements would be more than offset by the fuel savings they would incur over the lifetime of the vehicle – even at a relatively low average fuel price of $1.50 per gallon.[52]

Among the technological advances that can improve fuel economy are:

- **Smaller, more efficient engines.**
- **Direct-injection engines** that allow greater control of the engine's use of fuel.
- **Advanced transmissions** – such as five- and six-speed automatics and continuously variable transmissions – that allow a broader range of gear ratios.
- **Integrated starter-generators** that allow greater power and enable the vehicle to take advantage of some features of hybridization (such as idle-off).
- **Lightweight materials.**[53]

Manufacturing Experience and Consumer Acceptance

To date, at least seven automakers – BMW, Ford, Honda, Nissan, Toyota, Volkswagen and Volvo – have manufactured conventional vehicles certified for PZEV credit in California.[54] (See Table 3.) Most vehicles that have been certified as PZEVs thus far use a combination of technologies to achieve emission reductions.

While many of the various technologies listed above have been used for several years, it has only been within the last two years that automakers have certified conventional vehicles to PZEV standards. Thus, there is little information on the degree to which PZEVs have been welcomed by consumers. However – 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 would gain increased value from their PZEV-certified vehicles.

Moreover, the emission improvements attained by vehicles meeting the PZEV standard have thus far come at limited cost. CARB has estimated that the PZEV standards themselves add only $100 to the cost of producing a SULEV-compliant vehicle, while SULEVs cost between $100 and $300 more to manufacture than cars meeting current Ultra Low-Emission Vehicle (ULEV) standards.[56]

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 a ZEV program and some have limited distribution only to California.

With regard to fuel economy improvements, many advanced technologies are making slow but steady progress into the marketplace. All manufacturers have succeeded in wringing more power from smaller engines over the last several decades – although most of the gains have been channeled into increasing vehicle power, not reducing fuel consumption. Direct-injection engines have been used for years in diesel vehicles, and automakers are beginning to experiment with their use in gasoline vehicles. General Motors, Honda, Audi and Nissan have included continuously variable transmissions in some models of their vehicles.[57]

Cost

The anticipated additional cost of manufacturing vehicles to PZEV emission standards has dropped significantly over the last several years. In 2001, CARB estimated that it would cost approximately $500 to upgrade a SULEV-certified vehicle to PZEV standards. By 2003, that estimate had dropped to $100.[58]

Table 3: Model Year 2003 Partial ZEV Credit (PZEV) Vehicles[55]

Mfr.	Model	Fuel	Availability
BMW	325i	Gasoline	CA, MA, ME, NY, VT
Ford	Focus	Gasoline	Std. in CA, MA, NY
Ford	Focus Wagon	Gasoline	Std. in CA, MA, NY
Honda	Accord EX/LX	Gasoline	CA
Honda	Civic GX	CNG	Nationwide
Nissan	Sentra XE/GXE	Gasoline	CA
Toyota	Camry	Gasoline	CA
VW	Jetta	Gasoline	CA
Volvo	S60 FWD	Gasoline	CA
Volvo	V70 FWD	Gasoline	CA

The lower cost estimate has been demonstrated to be roughly accurate. In California, Toyota sells the same model Camry in both PZEV and non-PZEV versions, with no difference in price. Similarly, Honda markets a PZEV and non-PZEV version of the Accord, with a price differential of only $150.[59] While PZEV-certified conventional vehicles, unlike hybrids, are not guaranteed to save their drivers money in fuel costs, the 150,000-mile emission system warranty required under the PZEV standard protects consumers from any costs they might incur upon emission-system failure; another important financial benefit.

As for vehicles that achieve greater fuel economy, as noted above, significant improvements in fuel economy have been found to be technologically possible at no added cost to consumers over the lifetime of the vehicle.

Future Prospects

As the newest generation of emission-control and fuel-efficiency technologies are perfected in laboratories and produced in bulk, their performance should continue to improve and their price to drop. But much depends on the future of government standards for vehicle emissions and fuel economy. While the adoption of LEV II standards in several states – coupled with the more aggressive federal emission-control strategy reflected in the national "Tier 2" standards, which are scheduled for phase-in beginning in 2004 – have helped push emission-control technology forward, no similar impetus exists for the deployment of fuel-efficiency technology for conventional vehicles.

The one program that has succeeded in improving fuel economy and reducing greenhouse gas emissions from conventional automobiles is the federal Corporate Average Fuel Economy (CAFE) program. In the decade-and-a-half following enactment of CAFE standards, the "real world" fuel economy of passenger cars nearly doubled – from 13.5 MPG in 1975 to 24.4 MPG in 1988. Similarly, light trucks experienced an increase in real-world fuel economy from 11.6 MPG in 1975 to 18.4 MPG in 1987.[60]

However, the momentum toward more fuel efficient cars has not only stalled since the late 1980s, it has actually reversed. The federal government has refused to increase CAFE standards in more than a decade, and changes in driving patterns – including higher speeds and increased urban driving – have led to a real-world decrease in fuel economy. An EPA analysis of fuel economy trends found that real-world fuel economy for cars sold in 2001 was lower than it was for cars sold in 1988. Worse, real-world fuel economy for light trucks sold in 2001 was lower than for *any year* since 1981.[61]

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

North Carolina's ability to improve the fuel economy of vehicles sold in the state is severely constrained by federal law, which prevents states from adopting regulations that are "related to fuel economy standards." North Carolina does, however, have the power to adopt California standards – such as the LEV II and ZEV programs – that can reduce vehicle emissions and also has the ability to adopt economic incentives and implement state purchasing programs to spur the deployment of more fuel efficient vehicles that release less global warming-inducing carbon dioxide pollution into the atmosphere.

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 been the source of renewed interest, due to their efficiency and cleanliness.

Vehicle Characteristics

Battery-electric vehicles are attractive for several reasons. They 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 only store 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.

Nonetheless, automakers have manufactured and sold or leased more than 10,000 battery-electric vehicles over the past decade. Battery-electrics have fit the real-life driving needs of the public better than expected. Technological advances and new marketing concepts have made battery-electrics even more appealing. And battery-electrics remain the only proven automotive technology that releases no harmful emissions during the operation of the vehicle.

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 relax again when the requirements are eased.

Photo: Electric Vehicle Association of Canada

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

In the 1990s, in response to California's enactment of the ZEV program, major automakers such as Honda and General Motors began to develop battery-electric vehicles for sale in California. The Honda EV-Plus and General Motors EV1 were both introduced in 1997 with operating ranges of between 60 and 130 miles. Other automakers substituted electric motors for gasoline engines in their vehicles.

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 ZEV program.[62]

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.[63]

A few automakers, including Ford and Daimler-Chrysler, moved ahead with plans to sell "city" and "neighborhood" battery-electrics that travel at low speeds for short ranges but can be sold at lower cost. Ford's Th!nk division, for example, leased about 1,000 city electric vehicles.[64]

However, the issuance of a judicial injunction against the enforcement of the ZEV requirement in 2002 – and the subsequent delay in the implementation of the California ZEV 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. As a result, few battery-electrics are available for purchase or lease today.

But the experience of the past decade shows both that manufacturers can produce battery-electric vehicles and, perhaps more importantly, that consumers will buy and enjoy them.

Consumer Acceptance

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

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

- 80 percent of those surveyed were more satisfied with their EV than with their current gasoline car.
- 70 percent said they use their EV as their primary vehicle (93 percent of those had access to another vehicle).
- 74 percent said they use their EV more than three-quarters of the time. Only 46 percent said they expected to use their EV that much before taking ownership.
- 77 percent would lease another EV.[65]

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

- Almost 70 percent of California state employees who rented EVs through a state rental program said they would consider buying or leasing an EV, with many noting that EVs were easy to drive and performed well.
- Southern California Edison, which has put more than 4.5 million miles on more than 420 EVs, found that operating EVs is less costly than operating gasoline vehicles due to lower fuel and maintenance costs.
- 84 percent of public-sector fleet EV operators surveyed by Southern California Edison said they were satisfied with the performance of their EVs, and 96 percent of the agencies expressed interest in expanding their EV fleets.[66]

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

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 drivers in California have reported having to surmount major obstacles to obtain the vehicles. Until recently, consumers could not purchase EVs outright, but could only obtain them through leases – many of which carried restrictive terms. In other cases, 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.[67]

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

In order to drive an electric vehicle from a major automaker, you first have to get over the fact that you have to lease it. Then you have to figure out where you can get one. Then you have to wade through a raft of salespeople who would much rather have you purchase a gas car. . . . Once you do manage to get a hold of the right person, you have to prove to them that you can live with the "limitations" of an EV. After you have done this, you're allowed to be put on the waiting list for a car.[68]

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

The survey found that about one-third of California new car buyers would be "likely" or "very likely" to purchase an electric vehicle if the cost were similar to that of a conventional vehicle. Yet the survey also showed that those consumers would be turned off by policies similar to those used by automakers in California. For example, less than 27 percent of these "EV intenders" expressed interest in purchasing the types of vehicles offered by manufacturers during the MOA period – compact pickups, sub-compact sedans or coupes, sports cars, minivans and compact SUVs.[69] Another 40 percent said they would opt to purchase a gasoline vehicle if leasing was the only option for obtaining an EV.[70]

During CARB's 2000 biennial review of the ZEV program, numerous individuals and fleet operators testified that they wished to purchase additional EVs, but had been unable to do so. In written testimony submitted to CARB, Lisa Rawlins, an executive with Warner Brothers studios, detailed her company's frustrations with attempting to obtain EVs.

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

Rawlins said that at least 50 employees of Warner Brothers identified themselves as seriously interested in buying or leasing electric or other clean vehicles. "To say that we were frustrated by the lack of product and unresponsiveness of the automakers is an understatement," she said.[71]

In 2002, Toyota briefly took a different path, offering to sell – rather than lease – its RAV4-EV (previously only available to fleets) to individual consumers. It was the first time in recent history that a major automaker offered EVs for direct sale to consumers. Published reports stated that Toyota was aiming for between 300 and 360 first-year sales. Toyota dealers attempted to "screen" potential buyers and the company limited distribution of the vehicle only to a handful of dealerships where the hybrid Prius had sold particularly well.[72]

Still, despite these limitations, the RAV4-EV appeared to meet Toyota's initial sales expectations. Between February 2002 and January 2003, Toyota sold 286 of the vehicles in California, with 56 more orders pending fulfillment – for a total of 340 sales – and its model year 2003 RAV4-EVs all sold out.[73] However, in November 2002, the company announced that it would stop taking new orders for the vehicles and, in January

2003, announced that it was discontinuing the program, stating that "sales levels were very low."[74]

The assertion of automakers that no market exists for EVs – despite a consistent lack of availability of the vehicles – has been a drumbeat for more than a decade. A 1994 story in the *New York Times* announcing a pilot program for the GM Impact – a predecessor of the EV1 – quoted GM officials expressing skepticism about the product's ultimate success, despite the fact that requests to participate in the pilot program were two to three times what the company expected. The lead paragraph of the story read: "General Motors is preparing to put its electric vehicle act on the road, and planning for a flop."[75]

In its 2002 announcement that it was scrapping its Th!nk electric vehicle program, Ford again cited "limited consumer demand for current battery electric vehicles" despite the fact that its Th!nk city vehicle had never been offered for sale to consumers in the United States (it had only been available for sale overseas and for rentals and use in demonstration programs).[76] Interestingly, both Ford and Toyota made their retreat from EVs just several months after the judicial injunction against enforcement of the California ZEV program.

Despite the resistance of the major automakers, however, battery-electric vehicles remain a viable technology for many, if not most, applications. 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.

With continued development of battery-electric vehicle technology, even the legitimate issues of range and cost could be surmounted.

Cost

Full-function battery-electric vehicles are significantly more costly than conventional, gasoline-powered vehicles. CARB estimates the additional incremental cost of such vehicles at $17,000 in the near term.[77] Should battery-electric vehicles be produced in large volumes, this cost would likely decrease. Drivers of EVs also benefit from federal tax breaks, lower maintenance costs (fewer moving parts), and significantly reduced fuel costs. The EPA estimated that the 2003 Toyota RAV4-EV achieved 125 miles per gasoline gallon-equivalent (MPGGE) in the city and 100 MPGGE highway, and that drivers would save approximately $500 per year in fuel costs versus the gasoline-powered RAV4.[78]

While the cost of battery-electric vehicles remains prohibitive for many consumers, the fuel cost benefits – and the prospect of further technological refinement in future years – could make battery-electric vehicles more cost-competitive in the years to come.

Future Prospects

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

Currently, three major battery technologies are used in electric vehicles. Lead-acid (PbA) batteries are the lowest in cost, but also have the lowest range. Nickel-metal hydride (NiMH) batteries, such as those used in hybrid vehicles, have the potential to last for 100,000 miles or more without replacement. But they, too, have low ranges and come at a higher cost than lead-acid batteries. Lithium-ion batteries – such as those used in many consumer products – could provide further range, should technology continue to develop, but are currently plagued by a short life-span.

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.[79] Continued progress along this path could lead to even further improvements in the years to come.

Such progress appears possible, despite the lack of commitment by automakers to battery-electric vehicles. Research into improved batteries for hybrid-electric vehicles, as well as other consumer products, should continue to bring about advances in battery life and energy density and reductions in cost – all of which would improve the attractiveness of battery-electric vehicles in the future.

ADVANCED-TECHNOLOGY VEHICLES AVAILABLE TOMORROW

Plug-In Hybrids

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

Vehicle Characteristics

In comparison to conventional hybrid vehicles, plug-in hybrids require a larger battery, capable of powering the vehicle in all-electric mode for 20 to 60 miles without recharging. However, the battery is smaller than that of a traditional battery-electric vehicle, allowing the vehicle to be recharged overnight using a conventional 120-volt connection to the grid. As a result, plug-in hybrids could be significantly less expensive 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 or sole source of propulsion for the vehicle is the electric motor. Because fuel-cell vehicles will also be driven by an electric motor, the development of plug-in hybrids could serve as a crucial bridge between the two technologies.

Technological Challenges

The primary challenge to the creation of plug-in hybrids is the cost of the larger batteries needed for the vehicles. Current projections suggest that plug-in hybrids will cost between $1,500 and $6,000 more than conventional hybrids, depending on the vehicle's all-electric range.[80]

Another 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 has been somewhat resolved in the case of conventional hybrids by extended warranties offered by manufacturers and the longer life-span of nickel-metal hydride batteries. But the larger size of plug-in hybrid batteries, coupled with their increased importance to the performance of the vehicle, could raise concerns.

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 moved to demonstrate or produce a plug-in hybrid.

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. Routine maintenance costs for such a vehicle could be as much as $140 less per year than for a conventional car.[81] In addition, plug-in hybrids could also be used to 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 plug-in hybrid with 60 miles all-electric range – despite the higher projected costs of the vehicles. A dramatic increase in gasoline prices would spark even greater interest, while the need to replace the battery during the course of a vehicle's lifetime would dampen interest.[82]

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 great potential as a source of clean transportation in the decades to come.

Vehicle Characteristics

In essence, fuel-cell vehicles are electric vehicles without batteries. Electricity to drive the vehicle is derived through a chemical reaction involving hydrogen. Fuels such as gasoline and methanol can be used to generate the hydrogen needed, or hydrogen itself can be used as a fuel. When hydrogen is used, the only "emissions" from the fuel cell are water and heat. Other base fuels generate small amounts of hydrocarbon emissions, as well as carbon dioxide, but produce less pollution than conventional vehicles because of the superior efficiency of fuel cells as a means of propulsion versus internal combustion engines.

Technological Challenges

Like battery-electric vehicles, fuel-cell vehicles face significant challenges with regard to range. While prototype vehicles such as the Honda FCX have achieved ranges greater than those of battery-electric vehicles, the low energy density of compressed hydrogen gas makes it difficult to store enough hydrogen on board a vehicle to attain ranges similar to those of conventional gasoline-powered vehicles.

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.[83]

Another issue is the challenge of producing and delivering enough hydrogen to fuel a fleet of fuel-cell vehicles. Hydrogen can be produced through two processes: reformation of fossil fuels and other feedstocks, or electrolysis of water. Reformation of fossil fuels blunts the potential of hydrogen to limit the nation's dependence on fossil fuels and also results in significant emissions of air pollutants and carbon dioxide. Electrolysis – in which electricity is used to split water into its hydrogen and oxygen components – requires the use of a great deal of electricity. Should that electricity come from renewable sources, the entire process is emission-free from "well to wheels." But if it comes from fossil fuels – as is likely in the near term – the potential for significant pollution continues to exist.

Distribution of hydrogen would require the installation of equipment to create hydrogen at filling stations or the development of a system of hydrogen pipelines. New filling stations capable of dispensing hydrogen would also need to be created. The total cost of building this production, distribution and refueling network using current technologies is estimated to be upward of $500 billion.[84]

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.[85] 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.

In December 2002, Honda and Toyota delivered their first fuel-cell vehicles for lease to California government agencies and research institutions. The two companies have near-term commitments to lease 11 fuel-cell vehicles in California, with Honda planning to lease approximately 30 vehicles over the next two to three years.[86] Meanwhile, the first hydrogen filling stations have been built in California, Arizona and Nevada.[87] And in his 2003 State of the Union address, President Bush announced the proposed investment of more than a billion dollars into fuel-cell and hydrogen research, focusing public attention on the prospects of fuel cell development.

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. These investments will be more likely to occur if an initial market for the vehicles is guaranteed, as would be the case under the Zero-Emission Vehicle program.

GETTING ADVANCED-TECHNOLOGY VEHICLES ON THE ROAD: THE ZEV PROGRAM

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

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

History

The LEV II and ZEV programs have their 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 cars for 50 states. However, it preserved a special place for California, allowing the state to adopt tougher emission standards to address its unique air pollution problems.

By 1977, with more cities facing smog problems similar to those in California, Congress gave the states – through Section 177 of the Clean Air Act – the opportunity to adopt California's vehicle emission standards rather than sticking with the weaker national standards. Several states took advantage of that opportunity by adopting California auto emission standards – including the LEV/ZEV program – in the early 1990s.

North Carolina began to receive some of the benefits of the LEV program in 2001 with the state's inclusion in the voluntary National Low Emission Vehicle (NLEV) program. The NLEV program required automakers to provide cars meeting California emission standards in the Northeast beginning in 1999 and nationwide beginning in 2001. The program did not include a requirement for the sale of zero-emission vehicles. States participating in the NLEV program agreed not to adopt California standards (including the ZEV requirement) to take effect before the 2006 model year.

In California, meanwhile, the ZEV program itself was changing. As the initial 1998 compliance date for the original ZEV program crept nearer, California moved to add flexibility to the program. The original 1990 ZEV program required that two percent of automobiles sold beginning in 1998 be zero-emission vehicles, with the percentage increasing to five percent in 2001 and 10 percent in 2003. In 1996, however, the California Air Resources Board (CARB) – the body empowered to set auto emission standards in California – dropped all ZEV requirements from 1998 to 2003 in exchange for a commitment from major automakers to produce between 1,250 and 3,750 advanced battery-electric vehicles for sale in California between 1998 and 2000.[88]

In 1998, CARB amended the program again to allow manufacturers to receive partial ZEV (PZEV) credit for near-zero-emission vehicles. In 2001, CARB again revised the program to encourage the development of advanced-technology vehicles and 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.

Implementation of the program in California itself was pushed back until 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 ZEV program in that state for the 2003 and 2004 model years.[89] The injunction was based on a narrow legal argument made by automakers that one of the 2001 amendments represented a fuel economy standard, which states are not permitted to set under federal law.

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

How It Works

The ZEV program technically requires that 10 percent of all vehicles sold to be zero-emission vehicles beginning in 2005. In actuality, though, percentages of vehicles called for under the ZEV 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 latest proposed version of the California ZEV program reduces requirements for the sale of "pure ZEVs"; those vehicles with no tailpipe or fuel-related evaporative emissions. While final regulations to implement the ZEV program have yet to be published as of this writing, changes approved by CARB in April 2003 would require automakers to sell approximately 250 hydrogen fuel-cell vehicles nationwide between 2005-2008. The fuel-cell vehicle requirement would increase to 2,500 between 2009 and 2011, 25,000 between 2012 and 2014, and 50,000 between 2015 and 2017.[90]

The latest version of the program would not require the sale of any additional fuel-cell vehicles in North Carolina until 2012. However, adopting a ZEV program in North Carolina would allow automakers to claim California credit for fuel-cell vehicles placed in North Carolina, increasing the likelihood that a limited number of fuel-cell vehicles would find their way onto the state's highways. In addition, beginning in 2012, automakers would be required to sell hundreds of fuel-cell vehicles per year in North Carolina, with the numbers increasing steadily thereafter.[91]

Automakers still retain the option of providing battery-electric vehicles to meet the pure ZEV requirement by complying with the previous version of the ZEV program. Alternatively, automakers can meet one-half of their fuel-cell vehicle obligations under the new program with the sale of battery-electric vehicles, with 10 battery-electrics earning the same credit as a single fuel-cell vehicle. In early years of the program, manufacturers can earn significant credits toward compliance either through the sale of full function battery-electrics, or with "city" or "neighborhood" electric vehicles that have a smaller range and travel at lower speeds. Credits for neighborhood electric vehicles are scheduled to decrease over time, so that by 2006 they will count for only 0.15 of a full-function ZEV.[92]

Partial ZEV (PZEV) Credits

The law allows manufacturers to meet up to 6 percent of the 10 percent ZEV requirement by marketing ultra-clean conventional, gasoline-powered cars. To receive partial ZEV, or PZEV, credit, vehicles must meet LEV II's strict super-low-emission vehicle (SULEV) emission standards, have "zero" evaporative emissions, and have their emissions control systems certified and under warranty for 150,000 miles.[93] Intermediate volume manufacturers – those that sell fewer than 60,000 light- and medium-duty vehicles in California annually – may meet the entire ZEV percentage requirement with PZEV credits. Each PZEV receives a credit equivalent to 0.2 of a pure ZEV.

Advanced Technology PZEVs (AT-PZEVs)

Under the April 2003 proposed changes to the program, manufacturers would be allowed to satisfy up to 4 percent of the 10 percent ZEV requirement by marketing vehicles that meet basic PZEV criteria, but also include advanced features such as hybrid-electric drive or can 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 2.5 for a vehicle with 125-mile all-electric range.
- **Alternative fuel** – Vehicles that run on 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 0.25 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.[94]

The upcoming 2004 Toyota Prius will be the first hybrid vehicle to meet AT-PZEV standards. Honda's natural-gas powered Civic GX also meets AT-PZEV standards. If manufacturers fail to fulfill the 4 percent allocated to AT-PZEVs, they must sell pure ZEVs instead.

Other Features

Under the California rules, automakers can also receive credits for placing vehicles in demonstration programs, and can earn additional credit for placing vehicles in programs that allow for shared use of vehicles, use "intelligent" transportation technologies, or are linked to transit use.

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

Another important change adopted by CARB in 2001 is a gradual ratcheting up of the ZEV requirement from 10 percent to 16 percent over the next two decades, as shown in Table 4 (see next page). However, the ample opportunities for additional credits and multipliers available to manufacturers will significantly reduce the amount of ve-

Table 4: California ZEV Percentage Requirement[95]

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

hicles that must be sold – particularly in the early years of the program.

The complexity of the ZEV program credit scheme makes it impossible to predict how many of each type of vehicle will be on the road, but the state of California has estimated the number of vehicles sold that would be AT-PZEVs and PZEVs. Assuming the same percentage of vehicles would be sold in North Carolina, and assuming that the state would adopt identical requirements to those in place in California for the 2007 and subsequent model years, the following reflects the approximate number of vehicles in each category that would be required in North Carolina under the program. (See Table 5).

Adoption of the ZEV program, therefore, would result in the sale of hundreds of thousands of vehicles in North Carolina with hybrid-electric motors, advanced emission-control systems, and other advanced automotive technologies. And it would put the state in position to take advantage of further advances in the years to come, by requiring the sale of hundreds of "pure ZEVs" beginning in 2012.

Table 5: Estimated Sales in North Carolina Under ZEV Program[96]

Year	AT-PZEVs	PZEVs
2007	11,200	92,000
2008	17,000	104,700
2009	23,600	117,400
2010	26,300	130,000
2011	28,800	142,500
Total Sales	**106,900**	**586,600**

Why the ZEV Program Is Essential

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

The ZEV program achieves four important goals in hastening this technological shift.

Ensuring a Supply of Clean Vehicles

As noted above, consumer reaction to many types of advanced-technology vehicles has been positive. Yet, in North Carolina, 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 ZEV programs, but there is no guarantee of their availability in North Carolina. And while hybrid vehicles are not in short supply – and more models are coming in the next several years – the available choices of vehicle types are extremely limited.

The ZEV 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 or fuel economy, but could lead to even 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 ZEV 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 proposed changes to the ZEV program, should they be approved by California, would reduce the need for new refueling infrastructure for ZEV-compliant vehicles. The vast majority of vehicles required under the revised program would be conventional PZEVs and hybrid-electric vehicles, both of which run on gasoline.

However, automakers still retain the option of meeting the program's requirements by selling battery-electric, natural gas, fuel-cell and other types of vehicles that do not run on gasoline. Should automakers choose this compliance path, the ZEV 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 ZEV 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 ZEV program has thus far been a rousing success. For example, prior to California's 1990 adoption of the ZEV 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 program, the amount of patent activity skyrocketed: between 1992 and 1998, the number of EV-related patents increased by about 20 patents per year.[97]

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

The recent proposed changes to the ZEV program that reduce requirements for the development 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 technology. Meanwhile, the program will work to bring clean conventional vehicles and hybrid-electrics to the point of mass commercialization.

As a result, the ZEV program could be more accurately referred to in its present guise as a "technology guiding" program, pushing automakers to invest in bringing to market those technologies with a proven ability to achieve environmental benefits.

Cost

Critics of the ZEV 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 proposed changes to the ZEV program, however, any such concerns about cost are no longer valid. Should CARB implement its April 2003 proposed amendments to the program, the adoption of a ZEV program in North Carolina 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 2012 at the earliest. Automakers will retain the option to produce such vehicles – and earn extra credit toward ZEV-program compliance – in the meantime.

Instead, automakers will be required to sell thousands of vehicles with broad and proven consumer appeal – hybrids and clean conventional vehicles – and may choose to supply other advanced-technology cars such as natural gas vehicles. The incremental cost of these technologies is very low when compared to the base cost of the vehicles and automakers' annual sales.

Cost to Manufacturers

Assuming the requirements for vehicle sales in North Carolina presented above, and CARB's estimates for the cost of complying with those requirements using clean conventional cars and hybrids, the adoption of a ZEV program in North Carolina would cost automakers approximately $26 million in 2007 in technological improvements. Incremental costs would rise to $49 million in 2011. (See Table 6.)

These costs translate to an additional $252 per ZEV-compliant vehicle sold in 2007 or an average of $59 per light-duty vehicle sold in North Carolina.

To further put these costs in perspective, the $26 million estimated cost to automakers in 2007 represents:

- 0.4 percent of the money spent by new-car dealers on advertising alone nationwide in 2001.[98]
- 0.14 percent of sales by North Carolina new-car dealers in 2001.[99]
- 0.17 percent of the net income of the six major automakers during the last fiscal year for which complete data are available.
- 0.004 percent of the gross revenue of the six major automakers during the last fiscal year. [100]

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

First, vehicles sold under the ZEV program can be used by automakers toward compliance with other federal and state regulatory requirements. Should North Carolina adopt the Low-Emission Vehicle II (LEV II) program, of which the ZEV program is an integral part, automakers could use the ZEV and SULEV certified vehicles in their fleets to ease their compliance with LEV II's require-

Table 6: Estimated Cost of ZEV Program Compliance in North Carolina (in Millions)

Year	AT-PZEV	PZEV	TOTAL
2007	$16.83	$ 9.19	$26.02
2008	$25.58	$10.47	$36.05
2009	$28.32	$11.74	$40.06
2010	$31.57	$13.00	$44.57
2011	$34.56	$14.25	$48.82

ments for emissions of non-methane organic compounds, ozone-forming nitrogen oxides and other pollutants. Similarly, the more fuel-efficient hybrid vehicles sold under the ZEV program could help automakers comply with federal corporate average fuel economy (CAFE) standards. In other words, the manufacture and sale of ZEV-compliant vehicles makes it less likely that automakers will pay fines for failure to comply with other laws, or will allow them to sell additional larger vehicles with higher profit margins. In either case, the ZEV 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.[101]

The manufacture of clean vehicles could also improve automakers' corporate image. Toyota, for instance, has heavily marketed its Prius hybrid in an effort to bolster the firm's overall environmental image.

Finally, 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 ZEV program, North Carolina consumers will likely see little difference in vehicle prices, and many may benefit directly from the program.

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

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, a hybrid-electric car will save its owner more than $1,000 (present value) in fuel costs. Should hybrid-electric vehicles continue to come down in price, the result would eventually be a net economic benefit for consumers who purchase the vehicles.

Another potential benefit for consumers is the availability of government incentives for the purchase of advanced-technology vehicles. Federal incentives include tax deductions of $2,000 to $50,000 for purchase of clean fuel and hybrid cars, trucks, vans and buses. Deductions for clean fuel passenger vehicles are $2,000. In addition, a tax deduction of up to $100,000 per location is available for installation of refueling or recharging stations by businesses. However, this incentive is scheduled to be phased out beginning in 2004 and will end entirely in 2007.[102] The federal government has also offered a tax credit of up to 10 percent of purchase price or $4,000 toward the purchase of electric vehicles. This tax credit, however, is in the process of being phased out, and will end entirely in 2005.[103]

President George W. Bush has proposed tax breaks for hybrid vehicles as part his fiscal year 2004 federal budget. The fate of those subsidies remains uncertain as this report goes to press.

Many states have enacted tax breaks to encourage the purchase of alternative-fuel vehicles and the construction of alternative-fuel infrastructure. North Carolina has provided limited support for alternative-fuel vehicle development through Mobile Source Emission Reduction Grants, but funding for this program has recently been suspended due to budget cuts.[104] The creation of state-based program of financial incentives for the purchase of clean vehicles would provide yet another benefit for consumers and businesses who choose to buy cleaner cars.

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 North Carolina is beyond the scope of this report, but analysis conducted in California suggests that the state would have much to gain from adoption of a ZEV program.

As part of its most recent proposal to revise the ZEV program, CARB calculated the reductions in several air pollutants expected in the South Coast Air Basin (which includes Los Angeles) over the next two decades. CARB projected that, by 2020, the ZEV program would result in a 4 percent reduction in direct vehicular emissions of reactive organic gases (which contain air toxics and contribute to the development of smog) and a 3 percent reduction in emissions of nitrogen oxides. These emission reductions are on top of the already significant reductions generated by the LEV II emission standards and other efforts in California to limit pollution from motor vehicles.[105]

Conditions in California are not easily compared to those in North Carolina. But it is clear that adoption of the ZEV program would result in significant reductions in emissions of smog-forming, toxic, and greenhouse gas pollutants, at minimal cost to automakers, and with significant benefits to consumers.

Moreover, adoption of the ZEV program would set North Carolina on a path to enjoy the benefits of the next generation of cleaner vehicles as soon as they become available.

POLICY RECOMMENDATIONS

Adopt the LEV II and ZEV Programs

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

Other Measures

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

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

While the vast majority of vehicles covered by the ZEV program require no special infrastructure investments, several current and next-generation clean car technologies – such as natural gas, battery-electric and hydrogen fuel-cell vehicles – do require investments in refueling facilities and other forms of infrastructure.

The state can play an important role in the development of this infrastructure. State officials should provide leadership by working with multiple stakeholders to devise an alternative-fuel infrastructure plan for the state. Commitments of resources should be directed to areas of strategic importance – such as the state's interstate highway corridors – and should be used to leverage private investment in alternative fuel infrastructure. California and New York have demonstrated that state leadership in infrastructure development can pay dividends; North Carolina should follow their lead.

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

Incentives for the purchase of advanced-technology vehicles can help spur consumer and business demand for these vehicles. Any state tax incentive programs should be include incentives for the purchase of the cleanest hybrid-electric vehicles as well as incentives for the purchase of dedicated alternative-fuel vehicles. In addition, North Carolina should consider other creative measures to reward the purchase of cleaner cars.

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

Public awareness of zero- and near-zero-emission vehicles in North Carolina is low, but a public education plan leading up to the launch of the ZEV program could play a key role in the program's success. Such a program should not only clearly extol the environmental benefits of advanced technology vehicles, but should also promote the benefits to consumers and dispel the common misperceptions about advanced-technology vehicles, such as worries about vehicle range and safety. The allocation of state resources to this effort would be beneficial, but there are also other public and private resources that can be also leveraged for this effort.

Appendix: 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. Includes stringent limits on emissions from light- and medium-duty vehicles and the ZEV requirement.
LNG – Liquid natural gas.
MTCE – Metric tons carbon equivalent, a measure of greenhouse gas emissions.
MOA – Memorandum of Agreement negotiated between CARB and six major automakers in 1996 that eliminated interim ZEV requirements for 1998-2003 model years.
MPG – Miles per gallon.
MSRC – California Mobile Source Air Pollution Reduction Committee.
NiMH – Nickel metal hydride batteries.
NO_x – Nitrogen oxides.
PbA – Lead-acid batteries.
PZEV – Partial zero-emission vehicle credits.
RFG – Reformulated gasoline.
SULEV – Super-low-emission vehicle; the second-cleanest emission bin under the LEV II program and a prerequisite for qualification for PZEV credit.
SUV – Sport utility vehicle.
ULEV – Ultra-low-emission vehicle; the third-cleanest emission bin under the LEV II program.
VOC – Volatile organic compounds.
ZEV – Zero-emission vehicle.

NOTES

1. U.S. Environmental Protection Agency, *Light Duty Automotive Technology and Fuel Economy Trends, 1975-2001*, September 2001.

2. North Carolina Department of Environment and Natural Resources, Division of Air Quality, *Eight Hour Ozone Averages in 2002 in NC*, downloaded from http://www.daq.state.nc.us/monitor/data, 2 May 2003.

3. U.S. Public Interest Research Group Education Fund, *Danger in the Air*, August 2002.

4. U.S. Environmental Protection Agency, *National Emission Inventory: Air Pollution Emission Trends, Average Annual Emissions, All Criteria Pollutants, Years Including 1980, 1985, 1989-2001*, February 2003.

5. U.S. Public Interest Research Group Education Fund, *Dangers of Diesel: How Diesel Soot and Other Air Toxics Increase Americans' Risk of Cancer*, October 2002. Based on data from EPA's National Air Toxics Assessment.

6. Travis Madsen and Jasmine Vasavada, *Invisible Threats: Hazardous Air Pollutants and Cancer in New Jersey*, NJPIRG Law and Policy Center, 28 November 2001, 16.

7. U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation, *Climate Change and North Carolina*, September 1998.

8. Ibid.

9. Ibid.

10. Appalachian State University, Department of Geography and Planning, *North Carolina's $ensible Greenhouse Gas Reduction $trategies*, January 2000.

11. United Nations, Department of Economic and Social Affairs, Statistics Division, *Millennium Indicators Database*, downloaded from http://millenniumindicators.un.org/unsd/mi/mi_series_results.asp?rowID=576, 24 January 2003. Note: many former Soviet and Yugoslav republics did not report their emissions separately in 1990. Based on these countries' 1992 emissions, North Carolina would have ranked 33rd in the world.

12. Including former Eastern Bloc republics' 1992 emissions would drop the ranking to 57th.

13. U.S. Energy Information Administration, *Long Term World Oil Supply (A Resource Base/Production Path Analysis)*, downloaded from http://www.eia.doe.gov/pub/oil_gas/petroleum/presentations/2000/long_term_supply/tsld001.htm, 20 March 2003.

14. Some experts suggest that the peak in world oil production could occur even sooner. Much of their work is summarized at www.hubbertpeak.com.

15. Federal Highway Administration, *Highway Statistics*, years 2001 and Summary to 1995.

16. David Friedman, Union of Concerned Scientists, *A New Road: The Technology and Potential of Hybrid Vehicles*, January 2003.

17. General Motors, *GM Hybrid Trucks Deliver Better Gas Mileage, Go-Anywhere 110-Volt Power – Without Compromises*, (press release), 6 January 2003.

18. U.S. Environmental Protection Agency, *EPA and DOE Announce Fuel Economy Leaders for 2003 Model Year Cars* (press release), 29 October 2002.

19. California Air Resources Board, *2003 Model Year Guide to Passenger Cars*, updated 5 February 2003.

20. John Gartner, "Electric Vehicles Try to Turn Corner," *Wired News*, 14 December 2001; Toyota, *Hybrid Vehicle Lineup*, downloaded from http://toyota.irweb.jp/IRweb/corp_info/hybrid_tech_2001/5.html, 19 February 2002; Toyota, *Toyota Worldwide Hybrid Sales Top 100,000 Mark* (press release), 22 April 2002.

21. Toyota, *The All-New 2004 Prius*, downloaded from http://www.toyota.com, 21 April 2003.

22. General Motors, *GM Hybrid Trucks Deliver Better Gas Mileage, Go-Anywhere 110-Volt Power – Without Compromises*, (press release), 6 January 2003.

23. General Motors, *GM's Advanced Hybrid System Versatile, Effective*, (press release), 6 January 2003.

24. General Motors, *GM to Offer Hybrid Power on More than a Dozen Popular Models*, (press release), 6 January 2003.

25. Ford Motor Company, *Escape Hybrid FAQs*, downloaded from http://www.fordvehicles.com/escapehybrid, 21 April 2003.

26. *Taipei Times*, "DaimlerChrysler May Use Toyota Hybrid Drive," 10 January 2003, downloaded from www.evworld.com.

27. *Contra Costa Times*, "Hybrid Car Sales, Demand Picking Up," 4 January 2003, downloaded from http://www.evworld.com/databases/shownews.cfm?pageid=news040103-04, 21 February 2003.

28. Dow Jones Business News, "Hybrid Car Sales Up Amid War Fears," 14 March 2003.

29. See note 27.

30. J.D. Power and Associates, *J.D. Power and Associates Reports: Interest in Hybrid Technology is High, Especially Among Women* (press release), 6 March 2002.

31. California Environmental Protection Agency, Air Resources Board, *Staff Report: Initial Statement of Reasons: 2003 Proposed Amendments to the California Zero Emission Vehicle Program Regulations*, 10 January 2003.

32. Ibid.

33. See note 16.

34. California Air Resources Board, *2003 Model Year Guide to Passenger Cars*, updated 5 February 2003; California Air Resources Board, *2003 Model Year Guide to Trucks, Vans and Sport Utility Vehicles (SUVs)*, updated 4 February 2003.

35. U.S. Department of Energy, Alternative Fuels Data Center, *Alternative Fuel Station Counts Listed by State and Fuel Type*, downloaded from http://www.afdc.doe.gov/refuel/state_tot.shtml, 20 March 2003.

36. California Energy Commission, *California Clean Fuels Market Assessment 2001*, September 2001.

37. FuelMaker Corp., *Exciting New Product Lets You Fuel Your Car at Home* (press release), 8 October 2002.

38. Nedra Pickler, "Honda, FuelMaker Unveil At-Home Natural Gas Refueling System," Associated Press, 9 October 2002.

39. U.S. Department of Energy, Energy Information Administration, *Alternatives to Traditional Transportation Fuels 2000*, September 2002.

40. Based on California Environmental Protection Agency, Air Resources Board, *2003 Model Year Guide to Passenger Cars and 2003 Model Year Guide to Trucks, Vans and Sport Utility Vehicles*, downloaded from www.arb.ca.gov, 20 March 2003. Only CNG vehicles attaining an emissions rating of ULEV or greater are included.

41. See note 39.

42. M. Whalen, L. Eudy, and T. Coburn, U.S. Department of Energy, National Renewable Energy Laboratory, *Perspectives on AFVs: State and City Government Fleet Driver Survey*, April 1999.

43. U.S. Department of Energy, National Renewable Energy Laboratory, *Fact Sheet: Honda Civic Dedicated CNG Sedan*, May 1999.

44. "GM Releases 2002 Alternative Fuel Vehicle Pricing," *EnviroFleet*, Automotive Resources International, 29 October 2001.

45. U.S. Department of Energy, Clean Cities Program, *The Alternative Fuel Price Report*, 27 December 2002.

46. BP, *BP Statistical Review of World Energy 2002*, 18 June 2002.

47. U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2003 with Projections to 2025*, 9 January 2003.

48. See note 46.

49. American Council for an Energy-Efficient Economy, *Green by Design: Part 5: Tighter Tailpipe Limits*, downloaded from http://www.greenercars.com/gbd5.html, 4 March 2003.

50. Englehard Corp., *Engelhard Smog-Eating Technology to be Featured on BMW Cars in Five States* (press release), 18 July 2002.

51. John DeCicco, Feng An, Marc Ross, *Technical Options for Improving the Fuel Economy of U.S. Cars and Light Trucks by 2010-2015*, American Council for an Energy-Efficient Economy, July 2001.

52. Transportation Research Board, National Research Council, *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards*, 2002, 66-67.

53. See note 51.

54. See note 19.

55. Based on California Environmental Protection Agency, Air Resources Board, *2003 Model Year Guide to Passenger Cars and 2003 Model Year Guide to Trucks, Vans and Sport Utility Vehicles*, downloaded from www.arb.ca.gov, 20 March 2003. Availability based on information from automakers' Web sites.

56. California Air Resources Board, *Staff Report: Initial Statement of Reasons: Proposed Amendments to California Exhaust and Evaporative Emission Standards and Test Procedures for Passenger Cars, Light-Duty Trucks and Medium-Duty Vehicles "LEV II,"* 18 September 1998; California Air Resources Board, *Staff Report: Initial Statement of Reasons: 2003 Proposed Amendments to the California Zero Emission Vehicle Program Regulations*, 10 January 2003.

57. See note 51.

58. See note 31.

59. Ibid.

60. See note 1. The federal law that established CAFE standards also established the means for testing of vehicles to determine compliance with the standards. It has long been recognized that these testing methods overstate the "real world" fuel economy of vehicles and EPA has begun to include adjusted figures in its reporting of fuel economy trends.

61. See note 1.

62. California Environmental Protection Agency, Air Resources Board, *Staff Report: 2000 Zero-Emission Vehicle Biennial Review*, 7 August 2000, 4.

63. Toyota, *Toyota to Begin Selling Zero Emission Rav4-EV to California Retail Customers* (press release), 13 December 2001.

64. Clare Bell, "Excuses, Excuses!," *EV World*, 27 September 2002, downloaded from www.evworld.com.

65. See note 62, 75-78.

66. Ibid.

67. Ibid, 82-83.

68. Testimony of Chris Yoder before California Air Resources Board, 31 May 2000.

69. Green Car Institute, *The Current and Future Market for Electric Vehicles*, 4.

70. Ibid., 8.

71. Testimony of Lisa Rawlins, senior vice-president for studio and production affairs, Warner Brothers, before the California Air Resources Board, 31 May 2000.

72. Bruce Spence, "Toyota Looks for California Car Buyers Interested in All-Electrical Vehicle," *The Record* (Stockton, Calif.), 12 May 2002.

73. *Hartford Courant*, "Auto Notes," 18 January 2003.

74. Toyota, *RAV4-EV Frequently Asked Questions*, downloaded from http://www.toyota.com/html/shop/vehicles/ravev/rav4ev_0_home/, 21 February 2003.

75. Matthew L. Wald, "Expecting a Fizzle, GM Puts Electric Car to Test," *New York Times*, 28 January 1994.

76. Quote from Richard Parry-Jones, vice president, Ford Motor Company, obtained from Th!nk Mobility, *TH!NK Neighbor Production to Be Discontinued at End of 2002*, (press release), August 2002.

77. See note 31.

78. U.S. Department of Energy, U.S. Environmental Protection Agency, *Model Year 2003 Fuel Economy Guide*, 2002.

79. Dr. Thomas Turrentine, Dr. Kenneth Kurani, *Progress in EVs: 1990 to 2000: A Study for Cal ETC, Initial Findings*, testimony presented to the California Air Resources Board, 31 May 2000.

80. Electric Power Research Institute, *Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options*, 2001.

81. Ibid.

82. Ibid.

83. See note 31.

84. Marianne Mintz, Stephen Folga, John Molburg, Jerry Gillette, *Cost of Some Hydrogen Fuel Infrastructure Options*, Argonne National Laboratory, Transportation Technology R&D Center, 16 January 2002.

85. Bruce E. Tonn, Sujit Das, Oak Ridge National Laboratory, *An Assessment of Platinum Availability for Advanced Fuel Cell Vehicles*, 9 November 2001.

86. Hydrogen and Fuel Cell Letter, *Toyota, Honda Launch California Fuel Cell Fleets With Back-to-Back Events*, December 2002.

87. See note 36.

88. Michael Walsh, *California's Low Emission Vehicle Program Compared to U.S. EPA's Tier 2 Program*, 20 January 2000, 13.

89. Bill Moore, "California Injunction Blues," *evWorld*, downloaded from http://www.evworld.com/databases/printit.cfm?storyid=377, 22 July 2002.

90. California Environmental Protection Agency, Air Resources Board, *ARB Modifies Zero Emission Vehicle Regulation* (press release, 24 April 2003.

91. State of California, Air Resources Board, *Resolution 03-4*, adopted 24 April 2003.

92. California Environmental Protection Agency, Air Resources Board, *Zero Emission Vehicle Program Changes* (Fact Sheet), 23 February 2001.

93. In this case, "zero" evaporative emissions refers to emissions from fuel. Hydrocarbon evaporative emissions also come from other sources, including paint, adhesives, air conditioning refrigerants, vinyl, tires, etc. Source: California Air Resources Board, *California Evaporative Emission Test Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles*, I.E.1(2), adopted 5 August 1999.

94. California Environmental Protection Agency, Air Resources Board, *Staff's Suggested Modifications to the Proposed Regulation Order: Proposed 2003 Amendments to the California Zero Emission Vehicle Regulation*, 5 March 2003.

95. Ibid.

96. Sales projections are based on projected California sales of AT-PZEV and PZEV vehicles contained in the following documents: California Environmental Protection Agency, Air Resources Board, *Staff Presentation: Proposed Amendments to the Zero Emission Vehicle Regulation, March 27, 2003, April 24, 2003;* California Environmental Protection Agency, Air Resources Board, *Description and Rationale for Staff's Additional Proposed Modifications to the January 10, 2003 ZEV Regulatory Proposal*, 5 March 2003; California Air Resources Board, *Staff Report: Initial Statement of Reasons: 2003 Proposed Amendments to the California Zero Emission Vehicle Program Regulations*, 10 January 2003. Projected sales in North Carolina were derived by multiplying California sales estimates by .217, which represents the ratio of North Carolina car and light-duty truck sales to California car and light-duty truck sales for the year 2001, per Ward's Communications, *Ward's Automotive Yearbook 2002*, 271,272. Figures for 2007 through 2011 were further adjusted by multiplying the number of ZEV-required vehicles by a correction factor to account for the higher proportion of light-duty trucks in the North Carolina vehicle fleet. ZEV requirements for heavier light-duty trucks will phase in between 2007 and 2011, requiring a downward adjustment in estimated North Carolina ZEV sales figures. Because CARB had not completed revised regulations implementing the ZEV rule as of this writing, these projections should be considered preliminary.

97. A.F. Burke, K.S. Kurani, E.J. Kenney, *Study of the Secondary Benefits of the ZEV Mandate*, prepared for the California Air Resources Board, August 2000.

98. National Auto Dealers Association, *NADA Data: Advertising and the Dealership*, downloaded from www.nada.org, 19 March 2003.

99. National Auto Dealers Association, *NADA Data: Total Dealership Sales Dollars*, downloaded from www.nada.org, 19 March 2003.

100. Financial data for Ford, DaimlerChrysler, General Motors, Honda, Toyota and Nissan downloaded from Hoover's Online, http://www.hoovers.com, 19 March 2003. Based on fiscal year ending December 2002 for Ford, GM and Daimler Chrysler; fiscal year ending March 2002 for Honda, Toyota and Nissan.

101. Toyota, *Toyota RAV4-EV Leads the Charge to the Future* (press release), 15 September 2001.

102. U.S. Department of Energy, downloaded from http://www.fueleconomy.gov/feg/tax_hybrid.shtml, 23 July 2002.

103. U.S. Department of Energy, *Alternative Fuel Vehicle Fleet Buyer's Guide: Incentives, Regulations, Contacts: Federal*, downloaded from http://www.fleets.doe.gov, 26 February 2002.

104. North Carolina Department of Environment and Natural Resources, Division of Air Quality, *Mobile Source Emission Reduction Grants*, downloaded from http://daq.state.nc.us/motor/ms_grants/index.shtml, 5 May 2003.

105. California Environmental Protection Agency, Air Resources Board, *Description and Rationale for Staff's Additional Proposed Modifications to the January 10, 2003 ZEV Regulatory Proposal*, 5 March 2003.