

# **READY TO ROLL**

**The Benefits of Today's  
Advanced technology Vehicles for Oregon**

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**OSPIRG Foundation**

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# EXECUTIVE SUMMARY

**D**espite tighter federal air pollution limits for automobiles over the last three decades, Oregon's fleet of automobiles produces more global warming pollution than ever before, and toxic air pollution continues to threaten Oregonians' health. Increasing the use of advanced technologies and advanced technology vehicles would drastically cut Oregon's global warming pollution and help alleviate both toxic and smog-forming air pollution, while enhancing Oregon's energy security and boosting the state's economy.

Policies such as the Clean Cars program, which establishes standards for global warming pollution and toxic air pollution from new cars and light trucks and also requires the sale of low- and near-zero-emission vehicles, will help bring increased numbers of advanced technology vehicles to the state.

**Automakers' continued dependence on old and inefficient technologies is causing unnecessary levels of global warming pollution, toxic air pollution, and dependence on a volatile energy supply. These problems pose serious threats to Oregon's environment, public health, and economy.**

- The transportation sector, including cars and light trucks, is responsible for 38% of Oregon's carbon dioxide emissions which is the primary form of global warming pollution in Oregon. Global warming already threatens Oregon's environment. Scientists have measured a 50% decline in Cascades snowpack since the 1950s, reducing summer river flows and disrupting the state's water cycle. If current trends continue, pollution from cars and trucks will reach levels 31% higher than 1990 levels by 2020. Scientists

estimate that we must reduce pollution to 75% below 1990 levels by 2050 in order to avoid the most disastrous effects of global warming (pg. 10).

- Motor vehicles are a major source of toxic air pollution in Oregon. Every Oregon county has six or more toxic pollutants present in the air at levels that exceed EPA health benchmarks. High concentrations of air toxics such as benzene, formaldehyde, and acetaldehyde raise Oregon residents' cancer risk above federal health goals statewide (pg. 12).
- Oregon's over-reliance on petroleum for transportation leaves the state susceptible to rising prices, price spikes and supply disruptions, and sends millions of dollars out of state in unnecessary fuel costs. Oregonians spend roughly \$11.75 million dollars on gasoline every day, and nearly \$4.3 billion annually. Because Oregon has no oil production or gasoline refining capacity in state, the majority of the profits from gasoline sales accrue to companies outside of Oregon, hurting Oregon's economy and leaving less money in the hands its consumers and businesses. These problems will become more severe over the next several decades as global petroleum supplies tighten and prices rise (pg. 14).

**There are advanced technology vehicles—and advanced technologies for conventional vehicles—that can alleviate these problems. While the technologies are “ready to roll,” their availability in Oregon is limited.**

- **Clean conventional vehicles:** Automakers can make every car and truck in their fleet produce significantly less global warming pollution by using advanced technologies already in existence, such as advanced transmissions, direct-injection engines, and improved aerodynamics. Many of these improvements to make cars cleaner could also significantly increase fuel efficiency, enhancing Oregon's energy security and economy. In addition, fourteen automakers now manufacture conventional vehicles that meet California's rigorous partial Zero Emission Vehicle (PZEV) emission standards that significantly reduce toxic air pollutants. However, many of these vehicles are available only to consumers in states that have adopted the Clean Cars program (pg. 20).
- **Hybrid-electric vehicles:** Americans purchased 93,000 hybrid cars in the first six months of 2005, more than they purchased in all of 2004. Sales took off in late summer as gas prices rose. As many as 60 percent of potential vehicle buyers surveyed state that they would consider buying a hybrid, yet some Oregon auto dealers report waiting lists for the popular Toyota Prius hybrid. Hybrid-electric technology can cut global warming pollution from cars by one-third, as well as provide substantial reductions in toxic air emissions (pg. 26).
- Other types of advanced technology vehicles—such as **battery-electric vehicles** and—**“plug-in” hybrids**—also show the potential for significant environmental benefits, including zero or

near-zero emissions of toxic and global warming pollution (provided they are charged from a clean source of electricity). However, the auto industry must move these technologies to market more aggressively to make them available to the general public (pg. 36)

- **Fuel-cell vehicles** also offer significant potential for zero or near-zero emissions. But this promise only holds true if the hydrogen is generated from renewable resources; current federal investment is geared toward fossil-fuel and nuclear sources of hydrogen. There are also substantial infrastructure investment obstacles that must be overcome before hydrogen fuel-cell cars will be a broadly viable solution (pg. 38)

**Adopting the Clean Cars program will put tens of thousands of advanced technology cars, light trucks, and SUVs on Oregon's roads by the end of the decade, at minimal additional cost to automakers and a net benefit to consumers. The Clean Cars program's advanced technology vehicle requirements and its pollution standards will cut global warming and toxic air pollution from cars and light trucks.**

- The Clean Cars program's "Zero Emission Vehicle" requirements will result in sales of approximately 7,000 hybrid-electric vehicles and 30,500 ultra clean conventional gasoline-powered vehicles in Oregon in 2008 (when model year 2009 vehicles go on sale), with the numbers increasing over time (pg. 45).



- By 2016, the standards will reduce global warming pollution from new cars by 34 percent and from new light trucks by 25 percent. These cuts will reduce total global warming pollution from Oregon's cars and light trucks 12% below projected levels by 2020, the equivalent of removing 350,000 cars from Oregon's roads. (pg. 50)
- The air quality standards in the Clean Cars program will provide a 5 percent reduction in emissions of volatile organic compounds, including toxic air pollutants that threaten Oregonians health, over federal standards by 2020. Nitrogen oxide emissions will be reduced an additional 11 percent beyond cuts achieved by federal standards. (pg. 48)
- The Clean Cars Program will also ensure a consistent supply of clean vehicles for Oregon's consumers, create economies of scale to drive down costs, provide enough vehicles 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. (pg. 46)

**The Clean Cars program will provide a net benefit to consumers and businesses who purchase cars and auto manufacturers will only incur minimal costs.**

- The global warming pollution standards will provide a net benefit from the Clean Cars program for consumers. Because the cleaner cars will be less expensive to operate, the projected increase in the up front cost of new vehicles will be more than offset by decreased operating costs. When the program is fully implemented, vehicle owners in Oregon will experience a collective net savings of \$8 million annually (p. 53).
- Producing vehicles to meet the air-quality and Zero-Emission Vehicle targets would cost automakers approximately \$11.5 million in model year 2009. The incremental cost of the program in model year 2009 represents 0.038 percent of automakers profits in 2004. These costs will be offset by financial benefits for automakers because the technological improvements can be exported to other vehicle lines and can assist in complying with other regulatory standards. (p. 51).

The goals of the Clean Cars program are attainable and achieving them would be beneficial to Oregon.

The automobile has long shaped the cultural and physical landscape of America. America is the land that invented the automobile, the land of the drive-in movie theater, the drive-thru restaurant, of suburbia and super-highways. In America, our cars are symbols of freedom, excitement, status, and power. They are also one of our nation's largest sources of air pollution.

Public consciousness of automobile pollution is not new. In the 1970s more automobiles driving more miles led to severe smog and toxic air pollution problems in cities across the nation. In response, states began passing laws limiting automotive emissions of a set of pollutants including smog forming and many toxic air pollutants, and the federal government passed the Clean Air Act. The auto manufacturers fought against these laws claiming that compliance would be technologically impossible and economically disastrous. However, once these stricter air quality standards were passed, automotive engineers produced immediate advances in emission control technology to dramatically reduce per-mile emissions of the regulated pollutants without any economic hardship.

This story has repeated itself throughout the history of environmental regulations. In the 1990s, California created a program called Low Emission Vehicle standards that included a Zero Emission Vehicles (ZEV) requirement. The ZEV requirements mandated that auto manufacturers sell certain numbers of battery electric vehicles. The automakers made the same arguments about cost and technological feasibility as they did in the 1970s, but the standards passed anyway. In response to the ZEV requirements innovation spiked and the filing of patents relating to the development of battery electric vehicles went from declining at

the rate of 1 per year, to increasing at the rate of 20 per year. Many experts assert that this flurry of innovation allowed Honda to introduce the first hybrid gas-electric vehicle in 1997 and Toyota to follow shortly after with the Prius, well before hybrid technology would otherwise have become available. The lesson America learned has learned is that we can and should require our cars to be cleaner.

In recent decades, scientists have discovered a new threat to our environment and quality of life in Oregon: global warming. Last year, forty six distinguished Northwest scientists released a consensus statement on the effects of global warming. They found that current changes in temperatures are due to human emissions of global warming pollution. And they also found global warming was already affecting us here in Oregon. Sea levels are rising off parts of Oregon's coast and spring snowpack in the Cascade Mountains has declined 50% over the last half of the 20<sup>th</sup> century. These changes have severe consequences including eroding shorelines, increasingly severe storms, decreasing summer river flows and increasingly scarce water resources. In Oregon the transportation sector, including our cars and light trucks, is the second largest contributor to global warming pollution.

Oregonians have a proud legacy of environmental leadership, and have made individual and policy choices that lead the nation in curbing the negative environmental consequences of our transportation systems. Portland has more hybrids per capita than any other city, boasts an excellent public transportation system, and is by design one the most bicycle friendly cities in the nation. Furthermore, our state's progressive land use laws create dense population

centers, limiting sprawl and reducing the amount that Oregonians drive.

Unfortunately, these efforts are not enough to curb global warming pollution from Oregon's transportation sector and we have yet to sufficiently control one of the largest sources, our cars and light trucks. OSPIRG's modeling of global warming pollution shows that if we fail to take further action, global warming pollution from cars and light trucks in Oregon is projected to increase to over thirty percent above 1990 levels by 2020.

The good news is that the promise of a new generation of cleaner, more environmentally benign cars has never been brighter. We don't have to wait for a technological revolution to take action because we can significantly reduce global warming pollution even with technology available today.

The Clean Cars program would put large numbers of advanced technology vehicles onto Oregon's roads quickly. To do this the program has two components: global warming pollution standards, and air quality standards which include the technology driving Zero Emission Vehicle (ZEV) requirements. The global warming pollution standards require car manufacturers to significantly reduce carbon dioxide emissions from vehicles beginning with model year 2009. In order to meet the standards, they will have to utilize technologies more widely throughout their model lines. The ZEV requirements will increase the number of environmentally benign cars and trucks available to Oregonians by requiring each of the major automakers to sell significant numbers of hybrid-electric, ultra clean conventional, and other advanced technology vehicles. In addition to putting more of today's advanced technology vehicles on the road, meeting the Clean Cars program standards has the potential to spur the development

of the next generation of cleaner cars: battery-electric, plug-in hybrid, and hydrogen fuel-cell cars.

Unfortunately, the automakers have continued their habit of resisting common sense environmental protections. The vast majority of vehicles sold in Oregon today do not incorporate the latest in technological advances to curb global warming pollution. In fact, automakers have not made some of the most promising advanced technology vehicles easily available to Oregon residents, and technologies that are available are only found on select vehicles.

Even worse, the automakers are leading efforts to block our state from adopting the Clean Cars program. This past summer they ran misleading ads against the Clean Cars program and they successfully lobbied the legislature to insert an unconstitutional budget rider that our Governor vetoed. Then they sued our state challenging that veto in a last ditch effort to block or delay the Clean Cars program. Finally, they lobbied against the Clean Cars program while participating in the Governor's task force to discuss its implementation in Oregon.

This report shows that we have the technology we need to curb global warming pollution from cars and light trucks now. We can make simple changes like making our cars more aerodynamic, using better lubricating oil, and installing automatic transmissions with more gears. We can also spread the use of more advanced existing technologies like turbochargers and engines that shut off half of their cylinders when they are not needed. Both will dramatically reduce global warming pollution from conventional gasoline powered vehicles. This report also shows that we have advanced technology vehicles like hybrids and battery electric vehicles that produce significantly less harmful pollution than



conventional cars and that the next generation of even cleaner vehicles is just around the corner. Finally, it shows how the Clean Cars program will get these technologies onto Oregon's roads.

Adopting the Clean Cars program is an opportunity for Oregon to continue its legacy of national environmental leadership. Washington passed legislation

stating that they will adopt the Clean Cars program as soon as Oregon does. That means that by adopting the Clean Cars program, Oregon will have helped to create a Pacific clean car corridor from Canada to Mexico.

Oregon cannot let this opportunity 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 the build-up of greenhouse gases in the atmosphere, air pollution, and economic harm from periodic price spikes and supply disruptions.

## Global Warming

Global warming pollution poses serious threats to Oregon's environment and economy. Globally, average temperatures increased during the 20th century by about 1° F. Global temperatures have not increased at this rate any time in the last 1,000 years.<sup>1</sup> These recent warming trends cannot be explained by natural variables such as solar cycles or volcanic eruptions. Instead, they correspond to models of climate change based on human production of global warming pollution from the burning of fossil fuels.<sup>2</sup> If current trends in global warming pollution continue, temperatures could rise globally by an additional 2.5° F to 10.4° F over the period 1990 to 2100.<sup>3</sup>

The Pacific Northwest is warming even faster than global averages. Temperatures have increased between 1-3° F in the 20th century. Nearly every urban and rural temperature monitoring station has registered an increase in temperatures since 1920.<sup>4</sup> Scientists expect a continued warming of the Northwest by between 0.2° and 0.9° F per decade, for an increase of 2.7° F by 2030 and 5.4° F by the 2050s.<sup>5</sup>

These changes are already having a significant effect on the environment and could have dramatic impacts on our way

of life. One of the most serious consequences for Oregon is the decline of spring snowpack in the Cascade Mountains. Snowpack has declined by 50% over the last several decades and may be cut in half again by 2050, reducing summer and fall river levels.<sup>6</sup> Lower river levels could have disastrous effects on salmon migration, farm irrigation, and shipping.<sup>7</sup> Another impact already being measured is rising sea levels. On the central and northern Oregon coast (from Florence to Astoria), rising sea levels are submerging the land at a rate of 1.5-2 millimeters per year. The total increase between 1930 and 1995 was approximately 4 inches. Possible effects include an increase in severe storm activity, coastal flooding, and beach erosion.

The transportation sector is the second largest source of global warming pollution in Oregon, accounting for 38% of carbon dioxide emissions.<sup>8</sup> In order to reduce global warming pollution and prevent the most serious consequences of global warming, Oregon must reduce emissions from the transportation sector.

## Air Quality

Toxic air pollutants threaten the health of thousands of Oregonians statewide and some areas struggle to control smog and soot pollution. Mobile sources are a major contributor to smog, soot, and toxic air pollution in Oregon and with more cars driving more miles in Oregon, the threat to public health is likely to increase unless action is taken to reduce harmful motor vehicle emissions.<sup>9</sup>

## Air Toxics

Several specific airborne toxic chemicals pose a significant health threat to

Oregon residents. Among the air toxics released from cars and light trucks are:

- **Benzene**, which can cause leukemia and a variety of other cancers.
- **Formaldehyde**, a probable human carcinogen with respiratory effects.
- **Acetaldehyde**, a probable human carcinogen that has caused reproductive health effects in animal studies.

In the Clean Air Act amendments of 1990, Congress set a health goal of reducing the cancer risk from airborne toxins to one case of cancer for every one million residents following a lifetime of exposure. Yet in 1996 (the most recent year for which comprehensive data are available) residents of every Oregon county were exposed to toxic air pollutants at levels that exceeded the federal health based standards for concentration of air toxics. The concentrations of toxics in Oregon's air were sufficient to raise statewide average cancer risks above the federal health goal. Mobile sources of pollution (including cars, trucks and off-road equipment) contributed more of the added cancer risk from human activity than any other source.<sup>10</sup> (See Table 1.)

Table 1 shows that air toxics from mobile sources are raising concentrations of several air toxics to unsafe levels throughout Oregon. Residents of Multnomah, Clackamas, and Washington counties are at the greatest risk. In these counties, levels of 14 different toxic air pollutants exceed federal benchmarks for concentration levels. However, toxic air pollution is a problem statewide: every Oregon county has air pollution that exceeds federal benchmarks for at least six toxic pollutants. In 21 out of 36 counties, air pollution exceeds federal benchmarks for 10 or more toxic pollutants.<sup>12</sup>

### Smog and Soot Pollution

Smog and soot pollution are linked to increasing rates of serious health problems including increased cancer and respiratory problems. Smog and soot pollution also impairs visibility.<sup>13</sup>

While most of Oregon does not experience significant smog or soot (particulate matter) pollution, there are several notable exceptions. In the early 1990s the Medford-Ashland area had high levels of particulate matter in the air that violated the Clean Air Act and threatened resident's health. Due to an aggres-

**Table 1. Health Risk from Air Toxics Exposure in Oregon<sup>11</sup>**

	Estimated Average Oregonian's Exposure to Air Toxics (micrograms per cubic meter)	Health-Based Exposure Benchmarks (micrograms per cubic meter)*	Percent by which Oregon exposure exceeds health standard	Percent of Cancer Risk From Air Toxics Added by Mobile Sources*
Formaldehyde	0.88	.08	1000%	74%
Benzene	1.49	.13	1046%	90%
Acetaldehyde	0.56	.45	24%	44%

\*Based on federal cancer risk level of 1 per million residents.

sive emissions reduction strategy, the Medford-Ashland Air Quality Maintenance Area has reduced particulate pollution to levels mandated by the Clean Air Act and in 2004 they submitted their plan for meeting and maintaining compliance with the Clean Air Act to the EPA.<sup>14</sup> Currently, Oakridge is listed as failing to comply with the Clean Air Act due to high levels of particulate matter. Although the Lane Regional Air Pollution Authority reports that particulate matter last exceeded legal levels in 1993, they have not yet been recertified as complying with the Clean Air Act by the EPA, and must remain vigilant to keep particulate pollution in check.<sup>15</sup>

## **Energy Independence and Economic Security**

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

Even without a dramatic event such as an oil embargo or natural disaster, price and supply problems are likely to occur as worldwide demand rises and readily accessible sources of oil are exhausted. Increases in oil prices to record highs prior to Hurricane Katrina were due to economic growth in developing countries, instability in the Middle East, and supply limits in many oil-producing countries. These forces are part of the long-term trend influencing oil prices.

The U.S. Energy Information Administration (EIA) projects that, at current rates of growth in oil consumption, oil production worldwide will peak in about 2037, leading to shortages and dramatically higher prices.<sup>16</sup> 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.<sup>17</sup>

The negative economic effects of the inefficient use of petroleum are clear in Oregon. Oregonians consume approximately 4.2 million gallons of gasoline daily.<sup>18</sup> In Oregon, retail prices for regular grade gasoline have hovered right around \$2.80 in 2005.<sup>19</sup> That means that Oregonians are spending roughly \$11.75 million dollars on gasoline every day, and will spend nearly \$4.3 billion total in 2005.<sup>20</sup> Because Oregon has no oil production or gasoline refining capacity in state, the majority of the profits accrue to companies outside of Oregon, hurting Oregon's economy and leaving less money in the hands of its consumers and businesses.<sup>21</sup>

Federal and state air quality programs for cars and trucks have achieved relative success in controlling smog-forming pollution in most parts of Oregon. However, there are currently no federal or state standards in place to address global warming pollution, and more aggressive action is needed to control air toxics. Furthermore, with the rising price and increasing use of oil, Oregon needs effective tools to reduce our dependence. The development and widespread use of a new generation of advanced technology vehicles would help to address many of these problems.

## **What Is an Advanced technology Vehicle?**

An advanced technology vehicle can be defined as one that uses advanced engine technologies or cleaner, alternative fuels to achieve dramatically improved envi-

ronmental results. There are also many advanced technologies that can be utilized to make conventional gasoline powered vehicles significantly more environmentally friendly.

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.

### **Advanced technology Vehicles Available Today**

- **Clean conventional vehicles** – In recent years, automakers have begun to introduce conventional, gasoline-powered vehicles that incorporate technologies that produce substantial reductions in global warming pollution. There are also vehicles that are virtually free of toxic and smog-forming emissions.
- **Hybrid-electric vehicles** – Hybrid-electric vehicles, such as the Toyota Prius, Ford Escape hybrid and Honda Civic hybrid, use an on-board electric motor to assist the vehicle's gasoline-powered engine, resulting in significantly greater fuel economy than conventional vehicles. Unlike battery-electric vehicles, hybrid-electric vehicles do not need to be recharged through a connection to the electric grid.
- **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. Although electric vehicles produce no tailpipe emissions, their environmental performance depends upon how the electricity powering the cars was generated.

### **ADVANCED TECHNOLOGY VEHICLES AVAILABLE TOMORROW**

- **“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 a 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 fully discharged, the gasoline-powered internal combustion engine takes over propulsion of the vehicle. Like electric vehicles, the environmental performances of plug-in hybrids depend in part upon how the electricity powering the cars was generated.

### **ADVANCED TECHNOLOGY VEHICLES OF THE FUTURE**

- **Fuel-cell vehicles** – Fuel-cell vehicles are electric vehicles that generate their power through a chemical reaction involving hydrogen. The hydrogen may be reformed from natural gas or other fossil fuels, or created using electricity from fossil, nuclear or renewable sources. However, technological, cost, and infrastructure constraints mean that fuel cell vehicles will not be available to consumers in the near future. Furthermore, similar to battery electric vehicles and plug in hybrids, hydrogen fuel cell vehicles are only as environmentally benign as the energy sources used to produce the hydrogen fuel.

## **Benefits of Different Technologies**

Researchers with the Argonne National Laboratory have estimated the per-mile emission levels of a variety of existing and prospective automotive

technologies over the entire fuel cycle, from “well to wheels.”<sup>22</sup> Their analysis shows advanced technology vehicles can have lower emissions of global warming pollution, air toxics, smog-forming chemicals, and can reduce our reliance on fossil fuels.

### Impact on Global Warming Pollution

Many advanced technology vehicles rely on cleaner fuels or use available technologies to significantly reduce carbon dioxide, the primary pollutant responsible for global warming, versus conventional vehicles, as shown in Figure 1.

All of the advanced technology vehicles examined in the study emit significantly less global warming pollution per mile traveled than conventional vehicles.

As noted above, while battery electric vehicles do not produce global warming pollution from their tailpipes, generating electricity to power their motors may

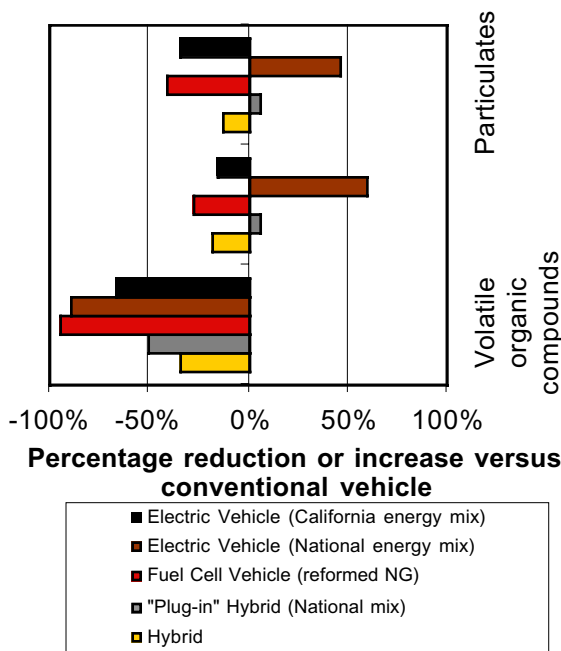
create pollution. Figure 1 shows that the mix of electricity generation sources used can make a substantial difference in how much global warming pollution electric cars are responsible for.

Vehicles powered by electricity from California’s energy are responsible for substantially lower global warming pollution than vehicles powered by the national energy mix, because much more of California’s energy comes from clean and renewable sources like solar and wind power than the national average (and less from dirty sources like coal and petroleum).<sup>24</sup> Because Oregon’s energy mix is cleaner than the national energy mix, electric vehicles in Oregon will also be cleaner than electric vehicles powered by the national energy mix.<sup>25</sup>

Hybrid vehicles also demonstrate significant reductions in global warming pollution per mile versus conventional vehicles. Because hybrid vehicles are not charged their reductions in global warming pollution do not fluctuate depending upon the electricity mix of their area of operation. However, the reductions in global warming pollution achieved by “plug-in” hybrids, do depend in part on the energy mix in their area of operation. Figure 1 represents a “plug-in” charged using the national energy mix under normal driving conditions.

It is important to note that fuel-cell vehicles are less developed and thus their environmental benefits are more speculative. The environmental impacts of hydrogen fuel cell vehicles also depend on the energy sources used to create the hydrogen. Hydrogen created from fossil fuel-based electricity will produce significant amounts of global warming pollution and hydrogen formed using power from nuclear energy creates radioactive waste that will remain dangerous for thousands of years. Furthermore, although hydrogen-powered vehicles can be virtually emission-free if the hydro-

**Figure 1. Per-Mile Carbon Dioxide Emissions of Advanced technology Vehicles<sup>23</sup>**



gen is generated by renewable energy, using renewable resources to power cars is a relatively inefficient use of clean power that could help offset demand for coal and other dirty sources of electrical generation.<sup>26</sup> Figure 1 represents a fuel cell vehicle using hydrogen from natural gas reformed using the national energy mix.



### Impact on Air Quality

The use of advanced technologies can significantly reduce toxic and smog-forming air emissions versus conventional, internal combustion engine vehicles operating on gasoline. Figure 2 shows the emissions of three air pollutants from advanced technology vehicles, compared to conventional gasoline vehicles. Particulates matter (soot) has been linked to increased hospitalizations and deaths due to cancer and heart and lung problems.<sup>27</sup> Nitrogen oxides (NOx) are a chemical component of smog. Volatile

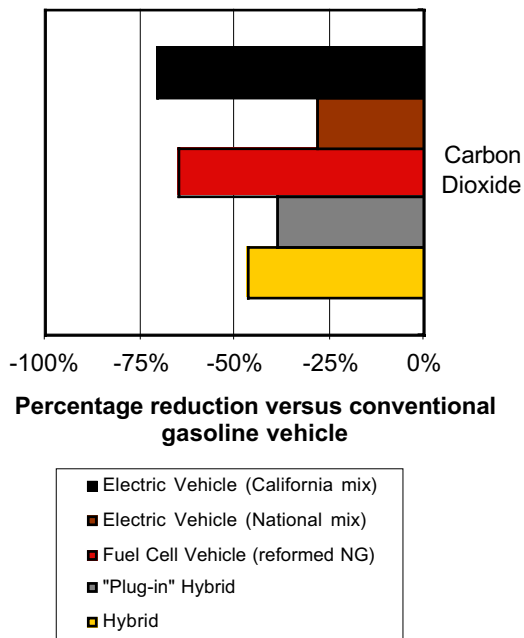
organic compounds (VOCs) are the chemical components that react with sunlight and NOx to form smog. They also include toxic air pollutants like benzene, acetaldehyde, and formaldehyde, that threaten Oregonians health (see table 1).

As with global warming pollution, the benefits of electric vehicles and

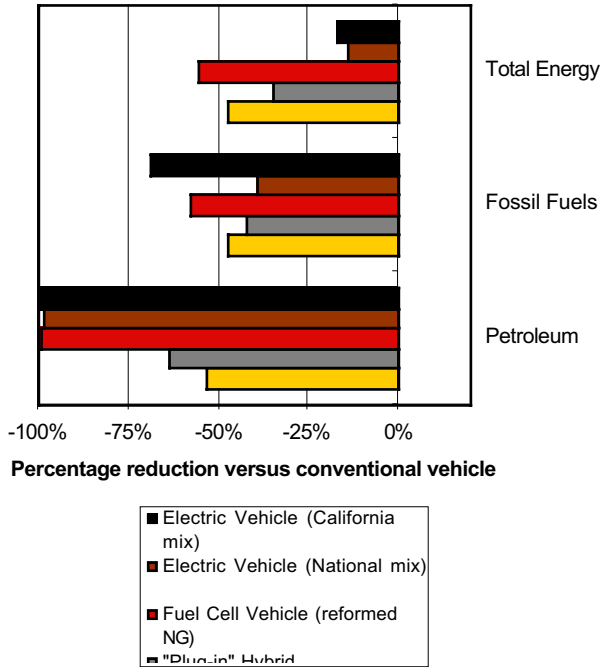
“plug-in” hybrids for reducing other forms of air pollution depend on the cleanliness of the energy mix used to generate the electric power they consume. Electric vehicles and “plug-in” hybrids powered by California’s energy will emit significantly lower levels of particulates, nitrogen oxides, and volatile organic compounds than conventional cars. However, electric vehicles and “plug-in” hybrids powered by the national energy mix will actually have increased emissions of nitrogen oxides and particulates.

Hybrid vehicles produce significantly less smog and soot pollution per mile than conventional vehicles. Fuel cells also have potential to produce significantly less smog and soot pollution. However, as previously noted, the methods used to generate hydrogen could cause substantial environmental damage and their environmental benefits are more speculative.

**Figure 2. Per-Mile Emissions of Advanced technology Vehicles<sup>28</sup>**



**Figure 3. Per-Mile Energy Use of Advanced technology Vehicles<sup>29</sup>**



### Energy Consumption

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

## The Need for Immediate Action

Today, there are more Oregonians driving more than ever before. In 2003 Oregon residents drove 34.5 million miles compared to 20.7 million miles in 1983 an increase of 66% in 20 years.<sup>30</sup> Unless Oregon acts, this trend is likely to continue and the major negative public health, environmental and economic consequences from automobile air pollution in Oregon will only increase. If Oregon doesn't act to control its global warming pollution, by 2020 cars and trucks will be emitting 31% more global warming pollution than they were in 1990. Scientists have estimated that by 2050, global warming pollution must be reduced to 75% below 1990 levels in order to stabilize the climate and avoid the most catastrophic effects.<sup>31</sup>

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

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



# ADVANCED TECHNOLOGY VEHICLES AVAILABLE TODAY

## EVALUATING ADVANCED TECHNOLOGY VEHICLES: THE ZEV REQUIREMENTS

In 1990, California created the Low Emission Vehicles program (the current package of policies that includes the original Low Emission Vehicles program will hereafter be referred to as the Clean Cars program), an aggressive air quality program for cars and light trucks. A key facet of the program required automakers to sell increasing numbers of zero-emission vehicles (ZEVs), which have no tailpipe emissions. The ZEV requirements have subsequently been modified to allow credit for vehicles with extremely low emissions. The standards used to award these credits are useful in evaluating the environmental performance of advanced technology vehicles.

A more detailed discussion of the Clean Cars program follows later in this report.

- Automobiles meeting the program's **Super-Ultra Low Emission Vehicle (SULEV)** standards release about 90 percent less smog-forming pollution than the average vehicle sold today.
- Vehicles that receive **Partial Zero-Emission Vehicle (PZEV)** credit must achieve SULEV emission standards, emit "zero" evaporative hydrocarbons, and come with an extended exhaust-system warranty.
- **Advanced Technology PZEVs (AT-PZEVs)** must meet all the standards of ordinary PZEVs, and must either include advanced technologies, such as a hybrid-electric drive, or be operated on cleaner alternative fuels, such as renewably-generated hydrogen.
- **Zero-Emission Vehicles (ZEVs)** are the "gold standard" for automobile environmental performance. ZEVs emit no harmful pollutants directly to the environment (although off-site generation of power or reformation of hydrogen to fuel ZEVs often creates pollution).

## Clean Conventional Vehicles

Clean conventional vehicles are not really advanced technology vehicles at all. Rather, they are the same cars and light trucks that are in common use today, but with technologies added to dramatically cut their pollution. There are a variety of simple technologies already in limited use that can address both global warming pollution and toxic air pollution.

## Automotive Technologies That Reduce Global Warming

An array of existing technologies reduce global warming pollution emissions dramatically compared to today's vehicles to today's vehicles, reducing Oregon's global warming pollution while at the same time improving the state's energy independence and benefiting the economy.

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

- **More efficient engines**, made possible through the use of turbocharging, in which a turbine recaptures the 25 to 50 percent of an engine's energy that is lost through exhaust and redirects it into the engine; or through variable compression ratios that allow an engine to tailor compression rates to load conditions.<sup>32</sup>
- **Direct-injection engines** that allow greater control of the engine's use of fuel.<sup>33</sup>
- **Advanced transmissions** – such as five- and six-speed automatics and continuously variable transmissions – that allow a broader range of gear ratios.<sup>34</sup>
- **Integrated starter-generators** that allow greater power and enable the vehicle to take advantage of some features of hybridization (such as idle-off).<sup>35</sup>
- **Improved air conditioning systems**, which may include a more efficient compressor, leak less, and use a refrigerant that contributes less to global warming.<sup>36</sup>
- **Weight reduction**, achieved through the use of lightweight materials such as high-strength low-alloy steel, aluminum, or magnesium alloys, or redesign to use less material in a car.<sup>37</sup>
- **More aerodynamic designs**, which can include a modified body shape or covers below the engine to reduce air drag.<sup>38</sup>
- **Cylinder deactivation** technology, which turns off half of the cylinders in the engine during some operating modes, such as steady-speed freeway driving.<sup>39</sup>
- **Improved lubricating oil** that reduces friction and cuts global warming pollution.<sup>40</sup>

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

A recent study by the Northeast States Center for a Clean Air Future (NESCCAF) quantified the potential global warming pollution reductions that are possible using existing advanced technologies. NESCCAF looked at different combinations of technologies applied to five different classes of vehicles, and concluded that emissions could be reduced by 14 to 54 percent by 2015. They found that for the largest cars, emissions reductions of 14 to 30 percent could actually *save* new car buyers up to \$1,900 over the life of the vehicle by lowering operating expenses.<sup>41</sup>

#### AUTOMOTIVE TECHNOLOGIES THAT REDUCE TOXIC AIR POLLUTION

To comply with the Clean Cars program in the states that have already adopted it, automakers are demonstrating their ability to make conventional, gasoline-powered vehicles that emit very little smog forming or toxic air pollution.

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

- **Exhaust gas recirculation** to reduce emissions of smog-forming nitrogen oxides.
- **Oxygen sensors** that allow adjustments in the air/fuel mix in a vehicle's cylinders in order to maximize the efficiency of combustion and ensure proper function of the catalytic converter.
- **Faster-heating catalytic converters** to reduce emissions that take place while a car is heating up.
- **Improved computerized control of the engine start-up sequence** to reduce "cold start" emissions (current emission-control systems are far less effective when cold).<sup>42</sup>

- “Smog-eating” coatings on radiators that convert ground-level ozone in ambient air into oxygen.<sup>43</sup>
- Modified fuel tanks and lines to control evaporative emissions.

In addition to implementing such technologies, automakers must stand by their durability and place the emission systems under warranty for 150,000 miles. Doing so commits automakers to dealing with a fundamental problem experienced by earlier generations of vehicles: degradation of the emission control system over time. The extended warranty also ensures that consumers do not face a financial burden to repair damaged emission control systems ensuring that cars covered by the warranty stay clean over the entire life of the vehicle.

## **Manufacturing Experience and Consumer Acceptance**

### ***Global Warming Pollution Reduction Technologies***

Many advanced technologies that reduce global warming pollution are making slow but steady progress into the marketplace. In the absence of global warming pollution standards during the last several decades, manufacturers have used these technologies to increase vehicle performance, size, and weight (without reducing global warming pollution). Turbochargers have seen widespread use in conjunction with already large and powerful engines to produce high performance cars like the Volvo S60 and numerous turbocharged Porsches. Direct-injection engines have been used for years in diesel vehicles and automakers are beginning to use them in gasoline vehicles like the 2005 Audi A4. Honda, Audi, Nissan, BMW, and

Saturn have included continuously variable transmissions in some models of their vehicles.<sup>44</sup> General Motors has introduced its Displacement on Demand technology, which allows the engine to use only half its cylinders during normal driving conditions.<sup>45</sup>

Manufacturers have ample experience integrating these technologies into their vehicles, and consumer acceptance of their use has been quite good.

### ***Air Pollution Reduction Technologies***

To date, at least 14 automakers have manufactured conventional vehicles certified for PZEV credit under the Clean Cars program. (See Table 3.) Most vehicles that have been certified as PZEVs thus far use a combination of technologies to achieve toxic and smog-forming emission reductions.

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

Moreover, the toxic and smog-precursor emission improvements attained by vehicles meeting the PZEV standard have 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.<sup>47</sup> The validity of this estimate is supported by the pricing decisions of several manufacturers. In states that have not adopted California’s Clean Cars standards, Ford sells PZEV and non-PZEV versions of the Focus. The PZEV version costs only \$115 more.<sup>48</sup>

**Table 2. Certified PZEV Credit Model Year 2005  
Conventional Vehicles<sup>46</sup>**

<b>Manufacturer and Model</b>	<b>Certification</b>	<b>Fuel</b>
BMW 325Ci coupe	PZEV	Gasoline
BMW 325i (sedan, wagon)	PZEV	Gasoline
Chrysler Dodge Stratus sedan	PZEV	Gasoline
Chrysler Sebring sedan	PZEV	Gasoline
Ford Focus wagon	PZEV	Gasoline
Ford Focus ZX3	PZEV	Gasoline
Ford Focus ZX4 (ST, sedan)	PZEV	Gasoline
Ford Focus ZX5	PZEV	Gasoline
Honda Accord sedan (LX, EX)	PZEV	Gasoline
Hyundai Elantra (GLS, GT)	PZEV	Gasoline
Kia Spectra	PZEV	Gasoline
Mazda 3	PZEV	Gasoline
Mazda 6	PZEV	Gasoline
Mitsubishi Galant	PZEV	Gasoline
Nissan Altima (2.5S, 2.5SL)	PZEV	Gasoline
Nissan Sentra (1.8, 1.8S)	PZEV	Gasoline
Subaru Legacy (2.5i, 2.5i-Ltd)	PZEV	Gasoline
Subaru Legacy wagon (2.5i, 2.5i-Ltd)	PZEV	Gasoline
Subaru Outback wagon (2.5i, 2.5i-Ltd)	PZEV	Gasoline
Toyota Camry	PZEV	Gasoline
Volkswagon Jetta	PZEV	Gasoline
Volvo S40 2.4i	PZEV	Gasoline
Volvo S60 2.4	PZEV	Gasoline
Volvo V50 2.4i	PZEV	Gasoline
Volvo V70 2.4	PZEV	Gasoline

To date, however, despite the small incremental cost of meeting the standards, most automakers have chosen to market PZEV-compliant vehicles only in states that have adopted the Clean Cars program.<sup>49</sup> Both American and foreign automakers have limited distribution of PZEVs to states that have adopted the Clean Cars program.<sup>50</sup>

### **Future Prospects**

As the newest emission-control technologies for global warming, toxic, and smog forming pollutants are perfected in laboratories and produced in bulk, their performance should continue to improve and their price should continue to drop. But much depends on the future of government standards for vehicle emissions and especially fuel economy. While the

adoption of the Clean Cars program in several states—coupled with the more aggressive federal emission-control strategy reflected in the federal—“Tier 2” standards, which are now being phased in—has helped push smog and toxic emission-control technologies forward, government policies to drive the deployment of technologies to reduce global warming pollution from conventional vehicles lag behind.

The easiest way to reduce global warming pollution from cars and light trucks is to increase fuel efficiency. However, states are not allowed to regulate fuel efficiency because that authority is preempted by the federal government’s Corporate Average Fuel Economy (CAFE) standards.

The CAFE program was adopted in 1975 as an energy conservation measure that has had the additional benefit of reducing global warming pollution from automobiles. In the decade-and-a-half following enactment of CAFE standards, the “real world” fuel economy of passenger cars nearly doubled—from 13.5 MPG in 1975 to 24.4 MPG in 1988. Similarly, light trucks experienced an increase in real-world fuel economy from 11.6 MPG in 1975 to 18.4 MPG in 1987.<sup>51</sup>

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

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

adopted, only a small number of vehicles sold were light trucks. Today, light trucks account for over half of vehicle sales.<sup>52</sup>

These vehicles are subject to less stringent fuel economy standards and thus have lowered the average fuel economy of vehicles driven today. An EPA analysis of fuel economy trends found that average real-world fuel economy for light-duty vehicles sold in 2004 was lower than it was for light-duty vehicles sold in 1987.<sup>53</sup>

The federal government recently approved a modest increase in CAFE standards for light trucks—from 20.7 MPG before 2003 to 22.2 MPG in the 2007 model year.<sup>54</sup> While this increase will spur the introduction of some technologies over the next several years that will reduce global warming pollution, much greater gains are technologically and economically feasible.

Federal policymakers have lagged far behind the auto manufacturers’ technological capability to produce vehicles achieve greater fuel efficiency and thereby produce less global warming pollution.

Fortunately, CAFE standards are not the only way to reduce global warming pollution from automobiles. States, exercising the authority given to them under the Clean Air Act, have begun to regulate global warming pollution directly by including fleet-wide global warming pollution standards in the Clean Cars program. These standards will significantly reduce global warming pollution from cars and light trucks and will spur the innovation of new global warming pollution reduction technologies.

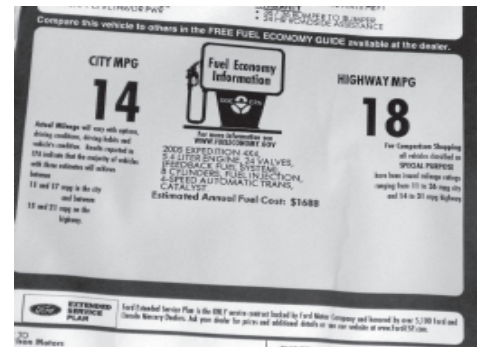


Photo: Sandy Ridlington

*The stagnation of federal fuel efficiency standards and increasing numbers of trucks and sport utility vehicles have contributed to increased global warming.*

photo: Sandy Ridlington



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

## Hybrid-Electric Vehicles

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

However, the development of advanced nickel-metal hydride batteries in the 1990s (driven by research conducted for battery-electric vehicles in order to comply with the ZEV requirements) and other automotive technologies led to renewed interest in hybrids.

### Vehicle Characteristics

Not all vehicles labeled "hybrids" by their manufacturers are alike. In fact, the term "hybrid" itself refers to a package of technologies, not all of which are included in every vehicle.

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

- The capability to shut off the conventional gasoline-powered engine when the vehicle is stopped.

- The use of regenerative braking, which captures energy that would otherwise be lost when a vehicle slows down.
- Reduced engine size versus conventional vehicles.
- The capability to drive the vehicle using only electric power.<sup>55</sup>

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

Many hybrids sold today do not possess all these traits, but the technological differences between hybrids does not automatically 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—cannot be driven by electric power alone.

Of greater importance is the percentage of a vehicle's power that is derived from the electric motor. The more that the vehicle relies on its battery, the less gasoline it uses.

For this reason, the Union of Concerned Scientists has defined one category of hybrids as "muscle hybrids"—vehicles that take advantage of hybrid features primarily to add power to the vehicle, not to bring about increased fuel efficiency or decreased emissions. For example, GM describes its hybrid Silverado pick-up truck as a "portable generator on wheels" because of its four 110-volt outlets.<sup>56</sup> The environmental benefits of this type of hybrid are minimal; the hybrid system in the Silverado, for example, boosts fuel economy by only 10 percent.<sup>57</sup>

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

Full and mild hybrid-electric vehicles have demonstrated clear environmental advantages over conventional vehicles. The three model-year 2005 full and mild hybrid-electric vehicles achieved an average EPA-rated fuel economy of 55 miles per gallon (MPG)—significantly more than the nearest gasoline-powered vehicle.<sup>58</sup>

In addition, most of the 2005 full and mild hybrid models are certified as Super Ultra-Low Emission Vehicles (SULEVs) under the Clean Cars program, meaning that their emissions are 90 percent cleaner than the average 2005 model year car.<sup>59</sup> Like the Honda Civic hybrid and Toyota Prius, Ford’s Escape hybrid meets AT-PZEV standards, and the vehicle, though an SUV, is ranked as having the 5<sup>th</sup> best fuel economy of all vehicles surveyed.<sup>60</sup> AT-PZEVs meet SULEV emissions standards, have “zero” evaporative emissions, and offer an extended emission system warranty.

## Manufacturing Experience

Toyota was the first major auto company to introduce a hybrid to the consumer market in 1997 in Japan. In the years since, Toyota, Honda, Ford and General Motors have expanded the availability of their hybrid vehicles in the United States.

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. The availability of hybrids to the general public has increased significantly in the 2005 model year. Honda began selling a hybrid version of the Accord, Ford started selling its Escape hybrid, and General Motors and DaimlerChrysler are now selling to retail customers a limited number of pickup trucks with modest hybrid capability. Toyota and Lexus expanded their hybrid offerings to include SUVs, Toyota adding the Highlander and Lexus the RX 400h. (See Table 3.)

**Table 3. Hybrid-Electric Vehicles Currently Available to the General Public**

Manufacturer	Model	Automatic Engine Shut-off?	Regenerative Braking?	Electric-only Drive?	Reduced Engine Size?	Model Year
Toyota	Prius	Yes	Yes	Yes	Yes	2005
Honda	Civic	Yes	Yes	No	Yes	2005
Honda	Insight	Yes	Yes	No	Yes	2005
Ford	Escape	Yes	Yes	Yes	No	2005
Lexus	RX 400h	Yes	Yes	Yes	No	2006
Toyota	Highlander	Yes	Yes	Yes	No	2006
Honda	Accord	Yes	Yes	No	No	2005
Dodge	Ram (diesel)	Yes	Yes	No	No	2005
Chevrolet	Silverado	Yes	Yes	No	No	2005
GMC	Sierra	Yes	Yes	No	No	2005

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

**Ford** – Ford has begun selling a hybrid version of its Escape SUV to the general public. The two-wheel drive version of the vehicle has an EPA fuel rating for in-city fuel economy of 36 MPG—an increase of more than 60 percent in-city and 24 percent highway fuel economy versus standard Escape models.<sup>61</sup> The Escape is the first SUV to take substantial advantage of hybrid technology. Ford performed much of the engineering work itself and supplemented that with several patents purchased from Toyota.<sup>62</sup> In January 2005, Ford announced that it will start selling a hybrid version of the Mercury Mariner SUV in fall 2005, a year earlier than originally scheduled.<sup>63</sup> And in September of this year, chairman and CEO Bill Ford announced that Ford would make hybrid versions available for half of their Ford, Mercury, and Lincoln models by 2010.<sup>64</sup>

**General Motors** – GM currently offers—"muscle hybrid" versions of its Sierra and Silverado trucks.<sup>65</sup> In 2006, GM plans to introduce a hybrid version of its model year 2007 Saturn VUE SUV that will get 10 percent better gas mileage than the standard model.<sup>66</sup> The company has announced that it will introduce a Chevrolet Malibu hybrid and two hybrid SUV's in 2007.

**DaimlerChrysler** – DaimlerChrysler introduced a diesel hybrid-electric version of its Dodge Ram 2500 pickup truck late in 2004, but only 100 of these diesel-electric vehicles will be available in the 2005 model year and their sale will be restricted to commercial fleets. Mercedes Benz debuted a hybrid version of their S-class sedan at the Detroit auto

show in 2005 although they have not announced a specific release date.<sup>67</sup>

Toyota and Nissan recently announced that they are planning to produce their hybrid models in the U.S. By the end of 2006, Nissan expects to manufacture a hybrid version of its Altima sedan at a U.S. factory.<sup>68</sup> Toyota has announced that it will begin producing a hybrid version of the Camry sedan in Kentucky next year.<sup>69</sup> Honda is also considering a similar shift in manufacturing location.

## Consumer Acceptance

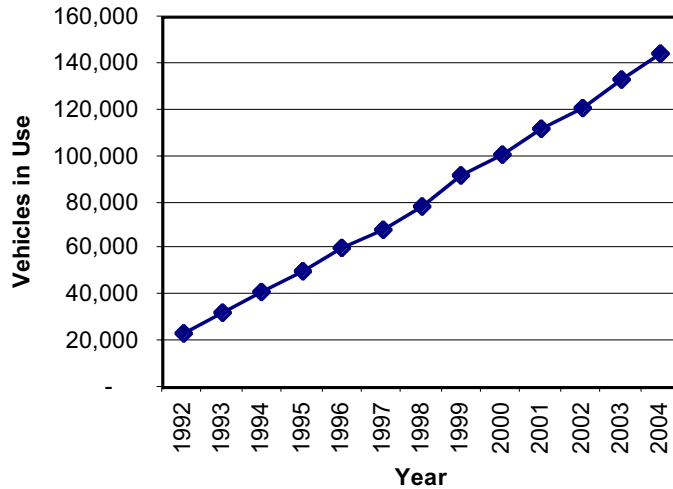
Hybrid-electric vehicles have met with a warm consumer response in the U.S., despite their somewhat higher initial cost and the limited number of models available. Many attribute the success of hybrids to their similarity to traditional gasoline-powered vehicles. Hybrids are fueled the same way, achieve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

While hybrids still represent only a small percentage of new vehicle sales in the U.S., that could change in the years to come. Sales of hybrid vehicles have increased rapidly since their introduction to the domestic market in December 1999. Between 2000 and 2004, hybrid sales have grown at an average annual rate of 74 percent.<sup>70</sup> About 85,000 hybrids were sold in the U.S. in 2004, an increase of 63 percent from the previous year.<sup>71</sup> (See Figure 4.)

Hybrid sales may be influenced by increasing oil prices and perceptions of insecurity regarding oil and gasoline supplies. Toyota and Honda reported 30 percent increases in sales of hybrids in the weeks leading up to U.S. military intervention in Iraq in March 2003, and Toyota reports that sales of the Prius doubled in 2004 compared to 2003.<sup>72</sup> J.D. Power and Associates, a firm that



**Figure 4. Hybrid-Electric Vehicle Sales, U.S.<sup>78</sup>**



studies the automotive industry, predicted that more than 200,000 hybrids will be sold in 2005 before the gas price spikes following Hurricane Katrina.<sup>73</sup>

As predicted, growth has remained strong in 2005. Americans purchased more hybrid cars in the first six months of 2005 than in all of 2004.<sup>74</sup> Japanese automakers are enjoying most of the increased hybrid sales. On August 31<sup>st</sup> 2005, Honda reached 100,000 hybrids sold to date in North America and Toyota has sold more than 93,000 of its popular Prius this year.<sup>75</sup> Over the next 10 years, conservative estimates project that more than one million hybrid vehicles may be sold in the U.S.<sup>76</sup>

Hybrids have also proven particularly popular in Oregon. As of April 2005, there were 5,253 hybrid vehicles registered in the state and Portland has more hybrids registered per person than any other city in the U.S.<sup>77</sup>

The market potential of hybrids has only begun to be tapped. A J.D. Power and Associates report found that 60 percent of new vehicle buyers would consider buying a hybrid-electric vehicle. Nearly one-third of those said they would buy a hybrid even if the added cost of the vehicle were not fully offset

by fuel savings.<sup>79</sup> Yet the market is failing to satisfy consumers' desire for hybrid-electric vehicles due in part to the failure of major American automakers to bring a hybrid to market until just this model year,

- Consumers who want to purchase the Toyota Prius have faced long waiting lists.<sup>80</sup> Toyota planned to increase production of the Prius by 50 percent in 2005 and to double it for 2006.<sup>81</sup>
- Ford reports that the waitlist for the Escape hybrid is two months long, on average.<sup>82</sup>
- More than 12,000 customers placed orders for Toyota's hybrid Highlander SUV before the vehicle went on sale.<sup>83</sup>
- Lexus began selling its first hybrid SUV in April 2005. Before a price had been announced, 9,500 vehicles had already been sold, 8,000 people were on waitlists, and 46,000 more people had expressed interest in the vehicle.<sup>84</sup> Lexus postponed the release of the SUV so that it could produce more vehicles and be better prepared to meet demand.<sup>85</sup>
- General Motors plans to build only 2,500 of its model year 2005 hybrid

Silverado and Sierra pickups. These hybrid pickup trucks are available in Oregon and five other selected states.<sup>86</sup>

## Future Prospects

While existing hybrid-electric vehicles have demonstrated significant per mile reductions in global warming, toxic, and smog pollution, even greater improvements are possible in the future. One 2003 study projected that the application of advanced technologies—such as continuously variable transmissions and advanced batteries—and more advanced hybrid systems could lead to a new-vehicle fleet average fuel economy of 50 to 60 MPG by 2020, reducing fuel consumption and cutting emissions even further.<sup>87</sup>

Achieving the full potential of hybrid electrics will not happen without effort. Public policies must be enacted to ensure not only that hybrids are made available to consumers, but also that those hybrids achieve significant toxic and global warming pollution reductions versus conventional vehicles and are not “muscle hybrids” designed merely to increase vehicle power.

## Battery-Electric Vehicles

Battery-electric vehicles are not a new technology. Indeed, many of the first generation of automobiles that hit Ameri-



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

Photo: Electric Vehicle Association of Canada

can roads in the late 19th and early 20th centuries were powered by electricity. However, by the second decade of the 20th century, when gasoline became widely available at low prices and internal combustion engines were perfected, electric cars became a thing of the past.

But in recent decades, battery-electrics have again received attention for their environmental benefits.

## Vehicle Characteristics

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

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

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

## Manufacturing Experience

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

In the 1990s, in response to California's enactment of the Clean Cars program's Zero Emission Vehicle requirements, major automakers began to develop battery-electric vehicles for sale in California. From 1998 to 2000, automakers sold more than 2,300 electric vehicles in California to fulfill the terms of a memorandum of agreement (MOA) with state officials.<sup>88</sup>

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 electric vehicles for fleet sales. Toyota, in fact, moved to expand the availability of its existing electric vehicle model, making the RAV4-EV—previously available only to fleets—available for individual lease in 2002.<sup>89</sup>

A few automakers, including Ford and DaimlerChrysler, moved ahead with plans to sell “city” and “neighborhood” battery-electrics that travel at low speeds for short ranges and can be sold at lower cost. Ford's Th!nk division, for example, leased about 1,000 city electric vehicles.<sup>90</sup>

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

Nonetheless, a few battery-electrics are available for purchase or lease today, and are quite popular. DaimlerChrysler's GEM division sells neighborhood electric vehicles—small cars powered by an electric motor and designed for use on short trips around town at speeds of 25 miles per hour—to consumers nationwide. Gizmo, another maker, sells with a range of 45 miles. Demand from this niche market is strong enough that prospective Gizmo buyers must wait for cars.<sup>91</sup> Neighborhood electric vehicles offer drivers an inexpensive, zero-emission transportation option for the short trips that make up most driving.

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

## Consumer Acceptance

Several surveys of electric vehicle owners in California show that drivers have been generally satisfied with their vehicles.<sup>92</sup>

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

Electric vehicle buyers in California reported having to surmount major obstacles to obtain the vehicles. Consumers reported sales staff who were unfamiliar with the vehicles, long delays in getting information, lack of clarity about their status on “waiting lists,” and long delays in obtaining vehicles once orders were placed.<sup>93</sup> Additionally,

automakers failed to offer types of vehicles that appealed to people interested in buying an electric vehicle.<sup>94</sup> And for most of the time period in which electric vehicles were available, consumers could not purchase them outright, but could only obtain them through leases—many of which carried restrictive terms.

A 2000 survey of California consumers conducted for the nonprofit Green Car Institute found that about one-third of California new car buyers would be “likely” or “very likely” to purchase an electric vehicle if the cost were similar to that of a conventional vehicle. Yet policies similar to those used by automakers in California reduced potential buyers’ interest: 40 percent said they would purchase a gasoline vehicle if leasing were the only option for obtaining an electric vehicle.<sup>95</sup>

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

### **Future Prospects**

While previous research into battery-electric vehicles has not yet yielded a ve-

hicle that can match the range and cost of a conventional car, progress toward those goals continues.

Three major battery technologies are used in electric vehicles, but thus far each suffers from high cost, limited driving range, and/or short life-span. In addition, all are bulky, limiting cargo space in the vehicle. Yet many of these problems also confront other vehicle technologies currently in development, such as hydrogen vehicles.

While battery-electric vehicles do have limitations, the pace of technological advancement in battery-electric vehicle development has been astounding. Between 1990 and 2000, the practical range of electric vehicles 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.<sup>96</sup> Argonne National Laboratory projects that by 2020, an electric vehicle equipped with a lithium-ion battery could have a range of 225 miles.<sup>97</sup> Though manufacturers are not currently producing full-function electric vehicles, they continue to pursue improved batteries and electric-drive technologies through their development of hybrid-electric and hydrogen fuel-cell vehicles. Continued progress along this path could lead to further improvements and greater application in the years to come.

# ADVANCED TECHNOLOGY VEHICLES AVAILABLE TOMORROW

## Plug-In Hybrids

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

## Vehicle Characteristics

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

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

Plug-in hybrids have significantly reduced global warming emissions compared to hybrid-electric and conventional

gasoline-powered vehicles. One study estimates that, through all stages of use, a plug-in hybrid SUV with a 60-mile all-electric range emits 60 percent less carbon dioxide than a conventional vehicle.<sup>98</sup>

## 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 hybrid cars will cost between \$2,000 and \$6,000 more than conventional hybrids, depending on the vehicle’s all-electric range.<sup>99</sup>

A technical challenge—similar to that faced by battery-electric vehicles—is the prospect for degraded battery performance over time, possibly requiring costly replacement. The battery life issue in the case of conventional hybrids has been somewhat resolved for consumers by extended warranties offered by manufacturers and the longer life-span of nickel-metal hydride batteries. But it may be of greater concern in plug-in hybrids, given the larger size of the battery and the increased importance of the battery to the performance of the vehicle.

Perhaps the largest challenge faced by plug-in hybrids, however, is the lack of interest automakers have shown in the technology. DaimlerChrysler has been the most active, developing a plug-in hybrid delivery van that it expects to test this year.<sup>100</sup> No vehicles for individual consumers are in development.

On the positive side, plug-in hybrids pose some distinct technological advantages. A plug-in hybrid car capable of 60 miles all-electric range that is fully charged each night could save its owner as much as \$380 per year in fuel costs versus conventional vehicles and a plug-

in hybrid SUV could reduce fuel costs by as much as \$880 (assuming fuel costs of only \$1.65 per gallon). Routine maintenance costs for such a vehicle could be as much as \$150 less per year than for a conventional SUV.<sup>101</sup> In addition, plug-in hybrids could also serve as emergency generators when the vehicle is not being driven.

### **Future Prospects**

Absent a commitment from automakers to the technology—or regulatory requirements or financial incentives that will spark automakers' interest—it does not appear that auto manufacturers will make plug-in hybrid cars available to the general public in the near term.

However, in May of 2005 Edrive systems, a Los Angeles based firm, announced the launch of aftermarket kits to convert a standard Toyota Prius hybrid into a plug in hybrid. Converted-Priuses would average 100 to 150 miles per gallon for approximately the first 60 miles traveled each day and have the capacity to run in—"electric only" mode at neighborhood speeds, producing zero emissions. The Edrive kit captures many of the potential benefits of plug-in hybrids, but because of its high cost (\$12,000) and the fact that installation voids Toyota's warranties, it will likely

appeal only to a small niche of consumers.<sup>102</sup> Mass production of plug-in hybrids by major auto manufacturers would address both of these problems and allow them to reach to a much wider demographic.

The benefits of the technology, combined with consumers' growing exposure to conventional hybrid technology and aftermarket kits, could cause automakers to take a second look at plug-in hybrids in the years ahead. For example, a recent survey found that 35 percent of mid-size car drivers studied would choose a plug-in hybrid with 20 miles all-electric range over a conventional vehicle, and 17 percent would choose a more-expensive plug-in hybrid with 60 miles all-electric range—despite the higher projected costs of the vehicles. Continued increases in gasoline prices would likely spark even greater interest.<sup>103</sup>

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 technology needed to manufacture the vehicles and the necessary refueling infrastructure already exists.

# ADVANCED TECHNOLOGY VEHICLES OF THE FUTURE

## 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. While fuel-cell vehicles possess potential as a source of clean transportation, significant problems remain to be resolved, including how to generate hydrogen in a safe and environmentally responsible way and how to build infrastructure necessary for refueling.

### Vehicle Characteristics

In essence, fuel-cell vehicles are electric vehicles without batteries. Electricity to drive the vehicle is derived through an electrochemical reaction involving oxygen and the car's supply of hydrogen in the presence of a catalyst such as platinum. (Fuel cell vehicles may also contain a battery to help the vehicle run more efficiently, in effect creating a hybrid fuel cell vehicle.)

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

- **Reformation** – Hydrogen is reformed from natural gas, biomass, or other fuels by exposing the fuels to high-temperature steam in the presence of a catalyst. The result of the process is hydrogen and carbon dioxide.
- **Electrolysis** – By exposing water to an electric current, water can be split into its constituent parts—hydrogen and oxygen. Electrolysis requires a large amount of electricity.

- **Gasification** – Using a super-heated reactor, coal, biomass, or other fuels are turned into a gas, which is then exposed to steam and oxygen to create hydrogen, carbon monoxide and carbon dioxide.

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

When renewable energy facilities are abundant enough to be used to process vast quantities of hydrogen, electrolysis and fuel cells may become a truly sustainable transportation power source. Nonetheless, a trade-off remains between using renewably generated electricity to create hydrogen for transportation and using that electricity to retire dirty power plants.

### Technological Challenges

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

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

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

The Department of Energy has set a goal of developing hydrogen-powered vehicles capable of traveling 300 miles on a tank of fuel—a range similar to today’s gasoline-powered vehicles.<sup>104</sup> Several fuel-cell vehicle prototypes have achieved driving ranges of 200 miles or more before refueling. But there is strong skepticism among some observers as to whether the storage problem can be resolved using current technology. In a 2004 report, the National Academy of Sciences (NAS) concluded, “[T]he committee questions the use of high-pressure tanks aboard mass-marketed private passenger vehicles from cost, safety, and convenience perspectives.... The committee has a similar view of liquid hydrogen.”<sup>105</sup>

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

Cost is also a major issue with regard to fuel-cell vehicles. The California Air Resources Board (CARB) estimates that fuel cell vehicles will cost \$120,000 to \$300,000 more than conventional vehicles in the short term. Assuming that automakers realize economies of scale from increased sales and production the increased cost would fall to \$9,300.<sup>106</sup>

Another issue is the challenge of producing and delivering enough hydrogen to fuel a fleet of fuel-cell vehicles. Hydrogen generated through the reformation of fossil fuels undermines the potential of hydrogen to limit the nation’s dependence on fossil fuels, curb global warming pollution, or reduce emissions of air pollutants. Electrolysis requires the use of a great deal of electricity. Should that electricity come from renewable sources, the entire process is emission-free from “well to wheels.” But if it comes from fossil fuels—as is likely in the near term—the potential for significant toxic and greenhouse gas pollution continues to exist. Further, leakage of hydrogen into the atmosphere from vehicles, pipelines, and fueling stations could affect the climate by allowing methane to remain in the atmosphere longer and altering cloud formation.<sup>107</sup>

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

A final challenge is the availability of substances to act as catalysts for the chemical reaction that creates electricity in the fuel cell. Currently, platinum is the primary substance used as a catalyst. Platinum is generally expensive, experiences wide price swings, and is supplied in large quantities by only two countries—South Africa and Russia.<sup>108</sup> Moreover, there is concern that the high demand for platinum that would result from the widespread introduction of fuel-cell vehicles could spark worldwide shortages of the metal.

### **Future Prospects**

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



Both Honda and Toyota began leasing a small number of vehicles for testing in California in late 2002.<sup>109</sup> New York and Nevada also lease vehicles.<sup>110</sup> Meanwhile, the first hydrogen filling stations in the U.S. have been built in California, Arizona and Nevada. There are none in Oregon.<sup>111</sup>

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

Not all of that research, however, has been focused on hydrogen systems that reduce economic and environmental risks. For example, the Bush administration's hydrogen research strategy has been heavily tilted toward the production of hydrogen from coal and nuclear sources'—both of which produce

significant environmental damage. Spending on fossil fuel and nuclear hydrogen research has increased dramatically over the past several years, and now represents more than one-third of Department of Energy spending on hydrogen-related programs.<sup>112</sup>

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

# GETTING ADVANCED TECHNOLOGY VEHICLES ON THE ROAD: THE CLEAN CARS PROGRAM

Despite the great advances in clean car technologies over the past decade, Oregon consumers are hard pressed to find advanced technology vehicles in their local car showrooms. With the partial exceptions of hybrid-electric cars (of which a limited supply of 10 different models are currently available) few advanced technology vehicles are available for sale to Oregon residents. One critical way Oregon policymakers can put more advanced technology cars on the road to Oregon is by adopting pollution standards that protect Oregon's air quality and cut global warming pollution.

The Clean Air Act gives states two options for controlling motor vehicle pollution. States may choose to comply with federal emission standards or adopt the more protective standards implemented by the state of California, the only state empowered by the Clean Air Act to develop its own emission regulations for cars and trucks. The most effective way to make sure that Oregon has increased access to advanced technology vehicles is by adopting the Clean Cars program, a package of air pollution regulations developed in California to control air pollution from cars and light trucks.

The Clean Cars program has two components that drive the deployment of advanced technologies. The first component, air quality standards, sets stringent limits on smog-forming chemicals and toxic air pollution. This component includes the technology-driving Zero-Emission Vehicle, or ZEV requirements, which require increased sales of advanced technology vehicles. The air quality standards, including the ZEV requirements, have existed in California for more than a decade. In addition to limiting smog, soot, and air toxic pollution, the ZEV requirements contribute to cut-

ting global warming pollution. A second component, global warming pollution standards, initiated in 2002 and taking effect in model year 2009, sets limits on global warming pollution from cars and light trucks.

## Air Quality Standards & the Zero-Emission Vehicle Requirements

The air quality standards reduce emissions by setting fleetwide limits on a set of gases that includes smog forming pollution and many toxic air pollutants. These standards drive technology as automakers implement state of the art emission control technologies to achieve compliance. But it drives technology most directly through the ZEV requirements which require minimum number of advanced technology vehicles to be sold. This section explains the ZEV requirements in detail before quantifying the global warming and air pollution reductions that result from this component of the Clean Cars program.

These advanced technology vehicle requirements, eventually call for the sale of zero-emission vehicles (ZEVs), and are therefore known as the ZEV requirements. By adopting the program, Oregon can lay the groundwork to have increasing percentages of advanced technology vehicles on the road over the next decade and beyond.

## How It Works

The ZEV requirements technically mandate that a percentage of vehicles sold in Oregon be zero-emission vehicles beginning in model year 2009. The percentage starts at 11 percent when the

program starts in model year 2009 and increased gradually to 16 percent starting in 2018 (see Table 5).

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

However, percentages of vehicles called for under the ZEV requirements do not represent real-world percentages of cars sold. Rather, automakers can 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 ZEV requirements only require small numbers of “pure ZEVs”—those vehicles with no tailpipe or fuel-related evaporative emissions. Prior to enforcement of the pure ZEV sales requirements for model year 2009, CARB will undertake a review of fuel-cell vehicle technology to ensure that it is feasible and available for the general market. If the review board determines that fuel-cell vehicles are not yet marketable, the sale requirement will be delayed.<sup>114</sup>

The ZEV requirements would not require the sale of any additional fuel-cell vehicles in Oregon until model year 2012. However, adopting the program in Oregon would allow automakers to claim credit for fuel-cell vehicles sold in Oregon before 2012, increasing the likelihood that a limited number of fuel-cell

vehicles would find their way onto the state’s highways. Once the requirements go into effect in model year 2012, assuming expected changes are made to existing regulations, the number of pure ZEVs required for sale in Oregon would be small, and automakers would be required to sell fewer than a thousand fuel-cell vehicles per year.<sup>115</sup> Even in the medium term the pure ZEV requirements remain small and will represent less than one percent of new car and light truck sales until model year 2018.<sup>116</sup>

Automakers still retain the option of providing battery-electric vehicles to meet the pure ZEV requirement. Automakers can meet one-half of their fuel-cell vehicle obligations under the new program with the sale of battery-electric vehicles, although it is not a one for one exchange. In early years of the program, manufacturers could 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. Manufacturers can use credits from early sales of these vehicles to reduce the number of ZEVs they must sell as the ZEV requirement increases.<sup>117</sup> Regardless of which compliance path automakers choose, they must put some pure ZEVs onto the road to meet the ZEV requirements.

### **Partial ZEV (PZEV) Credits**

The law allows manufacturers to meet up to three-fifths of the 10 percent ZEV requirement by marketing ultra-clean conventional, gasoline-powered cars. To receive partial ZEV, or PZEV, credit, vehicles must meet strict super-ultra low emission vehicle (SULEV) emission standards, have “zero” evaporative emissions, and have their emission

control systems certified and under warranty for 150,000 miles.<sup>118</sup> 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.<sup>119</sup>

### **Advanced Technology PZEVs (AT-PZEVs)**

Manufacturers are allowed to satisfy up to two-fifths of the 10 percent ZEV requirement by marketing vehicles that meet PZEV criteria and that also include advanced features such as hybrid-electric drive or run on alternative fuels such as compressed natural gas.

The value of an AT-PZEV under the program is determined by weighing a variety of factors that can increase or decrease the number of credits a vehicle receives towards the ZEV requirement:

- **All-electric range** – Vehicles that can travel at least 10 miles in electric mode (such as plug-in hybrids) are eligible for credits.
- **Alternative fuel** – Vehicles that run pressurized gaseous fuel (such as compressed natural gas) are eligible to re-

ceive credits. Vehicles capable of running entirely on hydrogen are eligible for an even greater credit.

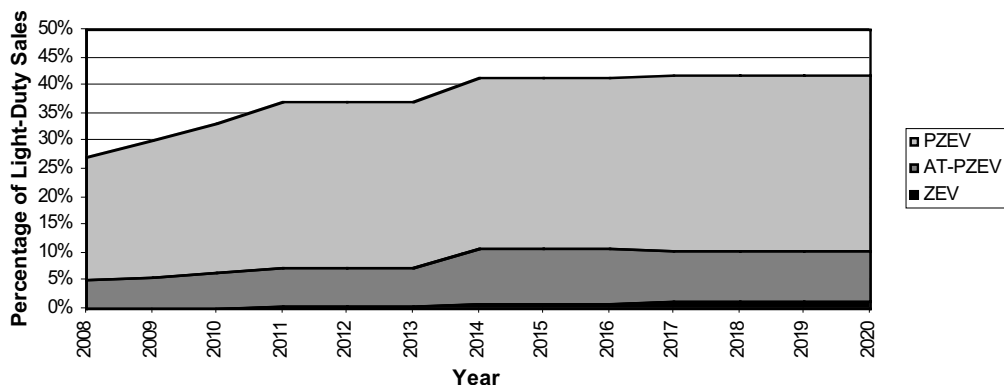
- **Hybrids** – Vehicles that include an advanced battery integral to the operation of the vehicle are eligible for additional credit. The credits are determined based on the voltage and amount of power provided by the hybrid system.
- **Clean fuels** – Vehicles that operate on fuels with very low emissions over their entire fuel cycles are also eligible for credits.<sup>120</sup>

Currently, the Toyota Prius, the Honda Civic hybrid, and the Ford Escape are the only gasoline-powered hybrid vehicles to meet AT-PZEV standards.

### **Other Features**

Under the ZEV requirements, automakers can also receive credits for placing vehicles in demonstration programs, and can earn additional credit for placing vehicles in programs that allow for shared use of vehicles and use “intelligent” transportation technologies (such as reservation management or real-time wireless information). Addi-

**Figure 5. ZEV Percentage of Light-Duty Vehicle Sales, 2008 through 2020**



tional credits are available if the vehicles are linked to transit use.

Assuming that manufacturers choose to satisfy the ZEV requirements with a mix of PZEVs and AT-PZEVs and that Oregon adopts the program beginning in model year 2009, hybrids could make up about 5.1 percent of Oregon car and light truck sales in 2008, increasing to 7 percent by 2012. PZEVs could make up nearly 30 percent of the market in 2008, increasing to more than 40 percent in 2014. (See Figure 5.)

Those percentages translate into carmakers selling approximately 7,000 AT-PZEVs and 30,500 PZEVs in the first year of the program. If CARB concludes that ZEV technology is ready for the consumer market, in model year 2012, manufacturers would have to sell nearly 600 pure ZEVs in Oregon. (See Table 6.) By model year 2016, manufacturers would be selling nearly 14,000 AT-PZEVs annually and more than 40,000 PZEVs.

Adoption of the Clean Cars program would result in the sale of tens of thousands of vehicles in Oregon with hybrid-electric motors, advanced emission-control systems, and other advanced automotive technologies. Furthermore, it would put the state in position to take advantage of further advances in the years to come, by requiring the sale of

“pure ZEVs” beginning as early as model year 2012.

## Benefits

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

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

## Ensuring a Supply of Clean Vehicles

As noted above, consumer reaction to many types of advanced technology vehicles has been positive. Yet, in Oregon, it is very difficult for consumers to purchase battery-electric vehicles. Ultra-clean conventional vehicles that meet PZEV standards are beginning to be offered for sale in states such as Massachusetts and New York that have already adopted the Clean Cars program, but there is no guarantee of their availabil-

**Table 5. Estimated Sales in Oregon under the LEV II Program<sup>121</sup>**

Model Year	PZEV	AT-PZEV	ZEV
2009	30,500	7,000	0
2010	33,800	7,800	0
2011	37,100	8,600	0
2012	40,500	9,800	570
2013	40,500	9,800	570
2014	40,500	9,800	570
2015	41,700	13,900	1,100

ity in Oregon. Hybrid vehicles are also in short supply and the available choices of vehicle types are extremely limited.

The Clean Cars 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 has significant advantages over conventional vehicles for the environment or for energy independence. 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 have little real impact on emissions, but rather use the hybrid technology to enhance 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 Clean Cars 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 ZEV requirements are structured in a way that reduces the need for new refueling infrastructure for pure ZEV vehicles. The vast majority of vehicles required under the revised program would be conventional PZEVs and hybrid-electric vehicles, both of which run on gasoline.

However, automakers still retain the option of meeting the program’s requirements by selling battery-electric, natural gas, fuel-cell and other types of vehicles that do not run on gasoline. Should automakers choose this compliance path, the ZEV requirements 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 requirements have traditionally been thought of as a “technology-forcing program”—driving automakers to invest in research and development efforts to create cleaner, environmentally preferable automobiles.

In this regard, the program has thus far been a rousing success. For example, prior to California’s 1990 adoption of the original LEV program, the number of patents issued for electric vehicle-related technologies was declining by about one patent per year. Immediately following the adoption of the ZEV requirement, the amount of patent activ-

ity skyrocketed: between 1992 and 1998, the number of electric vehicle-related patents increased by about 20 patents per year.<sup>122</sup> More recently, a similar trend has been documented for fuel-cell vehicle-related patents.<sup>123</sup>

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. While the original ZEV requirements were adjusted in response to automaker claims that the goals were set too high, technologies developed in an attempt to comply have found their way into the marketplace. Indeed, had the original ZEV requirements not been set high in California, it is doubtful that hybrid technologies would be as advanced as they are today.

To reflect their adaptive and responsive nature, the ZEV requirements could be more accurately referred to as a “technology-guiding” program, pushing automakers to invest in bringing to market those technologies with a proven ability to achieve environmental benefits.

### ***Environmental Benefits***

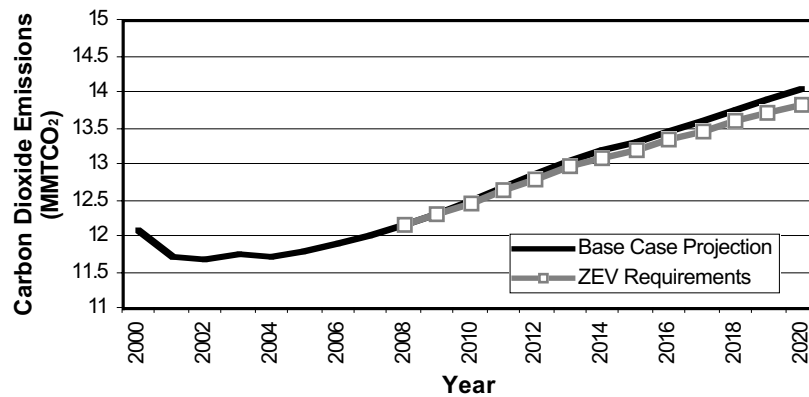
As noted above, advanced technology vehicles have the potential to achieve dramatically improved environmental performance compared to conventional vehicles. Quantifying the specific air quality impacts that would result from adoption of the program in Oregon is beyond the scope of this report, but analysis conducted for Connecticut, New Jersey and Rhode Island suggests Oregon would have much to gain from adoption of the air quality standards and the ZEV requirements in the Clean Cars program.

The Northeast States for Coordinated Air Use Management (NESCAUM), an association of state air quality agencies, performed an analysis of the air pollution benefits of the Clean Cars program, comparing it to federal clean air standards that would otherwise be in effect. While both programs reduce air pollution, NESCAUM’s analysis found that the Clean Cars program will provide an additional 5 percent reduction in emissions of volatile organic compounds, a category that includes several toxic air pollutants that threaten Oregonians health, over federal standards by 2020. Nitrogen oxide emissions will be reduced an additional 11 percent.<sup>124</sup>

Similar percentage emissions savings would apply to any state that adopted the Clean Cars program.<sup>125</sup> Thus it is clear that adoption of this program would result in significant reductions in emissions of toxic and smog-forming pollution.

While the ZEV requirements are technically part of the air quality standards in the Clean Cars program (not the global warming pollution standards), the technologies implemented as a result of the ZEV requirement contribute modestly to cutting global warming pollution. Based on assumptions outlined above, and assuming that any vehicles sold to meet pure ZEV requirements are hydrogen fuel-cell vehicles whose fuel is generated from natural gas, implementation of the ZEV program alone in Oregon beginning in the 2009 model year would reduce light-duty vehicle carbon dioxide emissions by about 1.4 percent versus base case projections by 2020—for a total reduction in emissions of about 0.2 million metric tons of carbon dioxide.<sup>126</sup> (See Figure 6.)

**Figure 6. Projected Reductions in Carbon Dioxide Emissions from Cars and Light Trucks Under ZEV Requirements<sup>127</sup>**



## Global Warming Pollution Standards

### How It Works

The global warming pollution standards set limits on the average emissions of all vehicles sold by a manufacturer in each model year. Average emission standards are set separately for two groups of vehicles, one for cars and small light-duty trucks, and another for larger light-duty trucks.

The standards will require near-term (2009 to 2012) reductions in average global warming pollution from cars and smaller light trucks by 25 percent and from larger light trucks by 18 percent. Over the medium term (2013 to 2016), the program will require reductions of 34 percent for cars and smaller light trucks and 25 percent for larger light-trucks.<sup>128</sup>

Carmakers may earn early compliance credits to offset the program's requirements by reducing the greenhouse gas pollution of the cars they sell in model years prior to 2009. For example, if a manufacturer's vehicles sold in model year 2007 have a grams-per-mile fleet

average lower than that required by the program in 2012 (the benchmark year), the maker earns credits that can be used in the first few years of the program.<sup>129</sup>

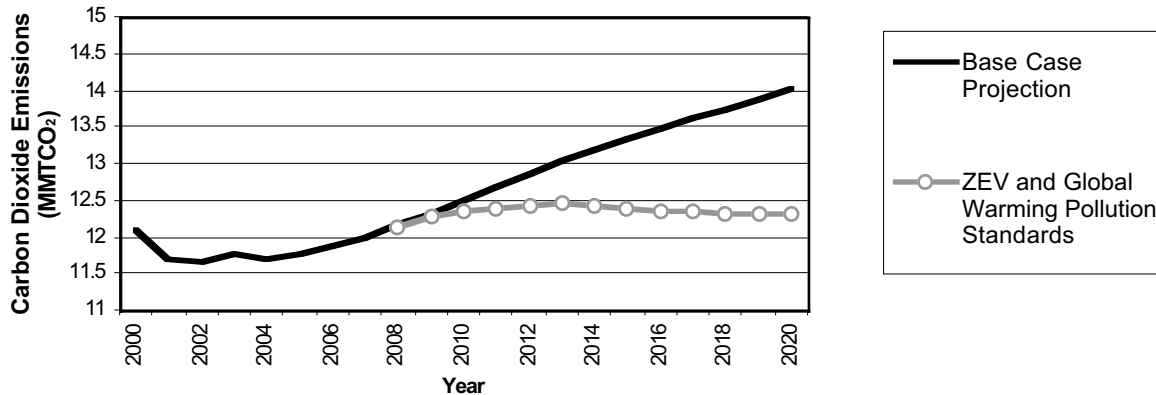
### Benefits

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

The reductions in global warming pollution that will result from the program are significant, even after accounting for expected increases in vehicle-miles traveled and for older vehicles still on the roads. Total carbon dioxide emissions from cars and light trucks would be cut by 12.3 percent by 2020—a total reduction of 1.7 million metric tons of carbon dioxide.<sup>130</sup> (See Figure 7.) This reduction—



**Figure 7. Reductions in Carbon Dioxide Emissions Under Global Warming Pollution Standards (Light-Duty Vehicles)<sup>131</sup>**



the equivalent of removing 350,000 cars from Oregon’s roads—would stabilize global warming pollution from cars and light trucks near 2000 levels.

### Economic Impacts of the Clean Cars Program

Critics of the program often suggest that the costs of the program will be too steep. Advanced technology vehicles, some argue, may be technologically feasible, but are too expensive to survive in the marketplace and will be too costly for manufacturers. However, the program offers a range of feasible compliance options to manufacturers and creates significant financial benefits to consumers due to decreased vehicle operating costs.

With the demonstrated market success of hybrids, any such concerns about cost are no longer valid. The adoption of the Clean Cars program in Oregon would likely require the manufacture of no additional

“pure ZEVs” such as battery-electric or fuel-cell vehicles—the most expensive vehicles to produce—until model year 2012 at the earliest. Automakers would retain the option to produce such vehicles—and earn extra credit toward

compliance with sales goals—in the meantime.

Instead, automakers will be required to sell thousands of vehicles with broad and proven consumer appeal—hybrids and clean conventional vehicles—and may choose to supply other advanced technology cars as they see fit. The incremental cost of these technologies is modest when compared to the base cost of the vehicles and automakers’ annual sales. In addition, the states that have already adopted the Clean Cars program represent 26 percent of the national car and light truck market.<sup>132</sup> This means that manufacturers have already invested in the research and production facilities necessary to provide advanced technology vehicles in Oregon.

### ZEV REQUIREMENTS

Assuming the requirements for vehicle sales in Oregon presented above, and CARB’s estimates for the cost of complying with those requirements using clean conventional cars and hybrids, adoption of the Clean Cars program’s ZEV requirement in Oregon would cost automakers approximately \$11.5 million in model year 2009 in technological improvements.

Though incremental costs fall over time, the total cost would rise to \$24.5 million in model year 2015 due to higher volume sales and the inclusion of a pure ZEV sales requirement.<sup>133</sup> (See Table 7.)

While these costs are by no means insignificant, they are part of a much larger picture. They represent only an additional \$305 per ZEV-compliant model year 2009 vehicle sold. Averaged over the entire fleet, it is \$83 per light-duty vehicle sold in Oregon. To put these figures in further perspective, the estimated cost to automakers in model year 2009 represents 0.038 percent of the \$30 billion in profits those automakers earned in 2004.<sup>134</sup>

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

First, vehicles sold under the Clean Cars program can be used by automakers toward compliance with other federal and state regulatory requirements. Should Oregon adopt the Clean Cars program, the hybrid vehicles manufacturers sell under the program—if they prove to be more fuel efficient—would also help automakers comply with federal corporate average fuel economy (CAFE) standards. In other words, the

manufacture and sale of ZEV-compliant vehicles such as hybrids makes it less likely that automakers will pay fines for failure to comply with other laws, or will allow them to sell additional larger vehicles with higher profit margins in Oregon and other states. Thus the ZEV requirements create offsetting financial benefits 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-electric vehicle, for example, have been used in the Toyota Prius, while information gleaned from electric vehicle and hybrid development programs is likely to play an important role in the development of fuel-cell vehicles.<sup>135</sup>

Finally, 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 fuel expenditures.

**Table 6. Estimated Cost of Compliance with ZEV Requirements in Oregon (in millions)**

Model Year	PZEV	AT-PZEV	ZEV	Total
2009	\$3.1	\$8.4	\$0.0	\$11.5
2010	\$3.4	\$9.4	\$0.0	\$12.8
2011	\$3.7	\$10.3	\$0.0	\$14.0
2012	\$4.1	\$11.7	\$5.3	\$21.1
2013	\$4.1	\$6.8	\$5.3	\$16.2
2014	\$4.1	\$6.8	\$5.3	\$16.2
2015	\$4.2	\$9.7	\$10.6	\$24.5

## Global Warming Pollution Standards

The technological changes needed to achieve the reductions required by the global warming pollution standards will likely result in modest increases in vehicle costs; however, these would be more than recovered over time by consumers in the form of reduced operating expenses.

CARB projects that cars and the lightest light trucks attaining the 34 percent reduction in global warming pollution required by 2016 would cost an average of \$1,064 more for consumers, while heavier light trucks achieving the required 25 percent reduction would cost about \$1,029 more.<sup>136</sup> However, the agency also estimates that the rules will significantly reduce operating costs for new vehicles. Though consumers will face higher monthly loan payments when purchasing vehicles that comply with the standards, those increased costs will be more than offset by lower operating expenses. For example, a consumer who buys a new car in 2016 will pay \$20 more per month on the car loan but will

save \$23 per month due to fuel savings, for a total savings of \$3 per month. After the loan is paid off, the consumer will save the full \$23 per month.

Assuming that the same number of cars and light trucks are sold annually in 2016 as are sold now and that every vehicle is financed with a loan, Oregon drivers who purchase a new car or light truck in 2016 collectively would save \$8.2 million. Once the loans for those vehicles are paid off, collective annual savings would be \$40.3 million. Savings of this level would accrue for vehicles purchased in other years, also.<sup>137</sup>

Drivers who purchase a light truck or who pay for the vehicle in cash will experience greater savings.<sup>138</sup> (See Table 7)

These savings assume gasoline costs of \$1.74 per gallon, so today's higher prices will increase consumers' net benefits.<sup>140</sup> CARB also projects that the net impact of the standards to the state's economy will be positive, suggesting that Oregon could save money while at the same time reducing the state's overall emissions of global warming pollution.<sup>141</sup>

**Table 7. Net Savings for Consumer Under Global Warming Pollution Standards in 2016<sup>139</sup>**

	Car	Light Truck
Increased Car Cost	\$1,064	\$1,029
Increased Monthly Loan Payment	\$20	\$19
Decreased Monthly Operating Cost	\$23	\$26
Monthly Net Savings	\$3	\$7

## POLICY RECOMMENDATION

Oregon should continue its legacy of environmental leadership and adopt the Clean Cars program this year. Putting more advanced technology vehicles on Oregon's roads is a critical tool for curbing global warm-

ing and other forms of air pollution. The Clean Cars program will put more advanced technology vehicles on the road and do so in ways that will also increase Oregon's energy security and boost Oregon's economy.

# 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.

**CO<sub>2</sub>** – Carbon dioxide.

**EV** – Battery-electric vehicle.

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

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

**MPG** – Miles per gallon.

**NO<sub>x</sub>** – Nitrogen oxides.

**PZEV** – Partial zero-emission vehicle credits.

**SULEV** – Super-low-emission vehicle; the second-cleanest emission bin in the Clean Cars program and a prerequisite for qualification for PZEV credit.

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

**VOC** – Volatile organic compounds.

**ZEV** – Zero-emission vehicle.

# METHODOLOGY

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

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

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

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