Maine Low Emission Vehicle and Zero Emission Vehicle Program Study

February 2004

Prepared by: Department of Environmental Protection

PZEVs

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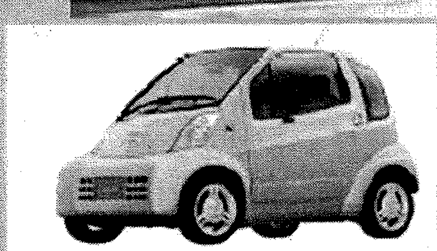

ZEVs

STATE OF MAINE
DEPARTMENT OF ENVIRONMENTAL PROTECTION

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February 26, 2004

To: Sue Jones, Natural Resources Council of Maine

From: Ron Severance, Director of Program Planning, BAQ, DEP

Subject: Zero Emission Vehicle "Study"

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Please find attached the following information on Analysis of California's Low Emission Vehicle Program including the Zero Emission Vehicle Program.

1. *Zero Emission Vehicle Study*, January 2000, Maine Department of Environmental Protection
2. White Paper, *Comparing the Emission Reductions of the LEV II Program to the Tier 2 Program*, October 2003, NESCAUM & Cambridge Systematics, Inc.
3. *The Drive for Cleaner Air in Connecticut: The Benefits of Adopting the California Low-Emission Standard for cars and Light Duty Trucks*, September 2003, Connecticut Fund for the Environment
4. *Clean Cars, Cleaner Air, How Strict Low-Emission and Zero-Emission Standards Can Cut AirBourne Toxic Pollution in New Hampshire*, April 2002, NHPIRG Education Fund
5. California Air Resources Board Fact Sheets:
    - California's Zero Emission Vehicle Program-2003
    - California Vehicle Emissions
    - Cleanest Gasoline Powered Vehicles
    - Alternative Fuel Vehicles
    - Hybrid Electric Vehicles
    - Battery Electric Vehicles
6. DriveClean.Ca.Gov
    - Vehicle Types and Vehicle Search
        - Electric
        - Hybrid Electric
        - Alternative Fuel
        - Fuel Cell
        - Cleaner Gas Cars
7. Light-Duty Hybrids Available Now & in Immediate Future, July 28, 2003, Center for a New American Dream, (spreadsheet)
8. *Emission Reduction Analysis for Maine from California Low Emission Vehicle Program and Zero Emission Vehicle Program*, February 2004, Maine Department of Environmental Protection (PowerPoint)

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Section One Introduction

In 1990, the California Air Resources Board (CARB) adopted a zero emission vehicle (ZEV) program. The original ZEV mandate required that by 2003 10 percent of the cars sold in California emit zero tailpipe and evaporative emissions. Vehicles that meet these criteria are called "pure ZEVs." In 1998 CARB revised ZEV program to allow manufacturers to fulfill a portion of the ZEV mandate with a variety of vehicles, including those powered by internal combustion engines. The revised ZEV mandate is called the "partial ZEV" program.

To date the ZEV requirement has been instrumental in promoting battery and vehicle research and development. As a result, a variety of battery-powered electric vehicles are now available to fleets and the general public. The program has also been successful in spawning a large variety of extremely low-emission vehicle technologies, many of which may not have gained significant attention without the CARB ZEV requirements. Many of these technologies have at least some qualities inherent to ZEVs, such as extremely low emissions and extended durability, partial all-electric range or the use of an inherently durable non-combustion engine. In response to the growing alternatives to battery electric ZEVs, CARB developed the partial ZEV program. The program introduces significant flexibility into the ZEV mandate and broadens the scope of vehicles that can qualify for meeting some portion of the ZEV requirement.

Some of these advanced technology vehicles will have equivalent air quality benefits as battery electric vehicles, namely: zero tailpipe emissions, zero evaporative emissions and no emissions associated with refining of fossil fuels. However others will only provide partial benefits in comparison with battery electrics. The partial ZEV program is intended to encourage the development of these new advanced technology vehicles. The reason for establishing the additional flexibility in the ZEV program is two-fold:

1) new advanced technology vehicles are being manufactured that have ZEV-like characteristics including the ability to operate on all-electric power and near zero emissions; and

2) the jump to 10 percent ZEV sales in 2003 will be difficult for automobile manufacturers. The partial ZEV program encourages the introduction of advanced technology vehicles and smoothes the transition to the 2003 ZEV requirement.

When California first introduced the zero emission vehicle mandate in 1990 only battery electric cars could meet the zero tailpipe emission standard. While technology advances have been made, battery electric vehicles are still limited to certain niche markets due to a limited driving range and a lack of re-charging infrastructure. Other recent technology advances have made the sale of natural gas hybrids, gasoline hybrids, and near zero gasoline conventional vehicles a reality. In addition, auto manufacturers have announced development programs for fuel cell cars and anticipate introduction of these vehicles in the next five years.

The development of alternatives to battery electric vehicles will make the use of cars with zero tailpipe emissions possible for the general public. In many cases, the public will not even be aware that they are driving in an advanced technology vehicle. For example, the driver of a gasoline hybrid vehicle will re-fuel the car at a gas station, will have extended mileage, and enjoy performance that is identical to that of a current gasoline car. At the same time, these advanced technology vehicles will reduce pollution and fuel consumption significantly.

Section Two Background

California's Low Emission Vehicle Program

Emission standards for passenger cars were first established in California in 1965. U.S. federal standards followed in 1968. Over the past thirty years these emission standards and test procedures have become increasing more stringent resulting in significant reductions in motor vehicle emissions.

In September 1990, the California Air Resources Board (CARB) adopted Low-Emissions Vehicle regulations. These regulations required automobile manufacturers to introduce progressively cleaner light- and medium-duty vehicles with more durable emission controls. The regulations included three major elements:

- They established a tier of vehicle categories to distinguish between increasingly more stringent exhaust emission standards for light- and medium-duty vehicles. In order of increasing stringency, the categories are:

  transitional-low-emission vehicles (TLEVs),

  low-emission vehicles (LEVs),

  ultra-low-emssion vehicles (ULEVs), and

  zero-emission vehicles (ZEVs).

- They required each manufacturer to phase-in a progressively cleaner mix of low-emission vehicles beginning in 1994 through 2003. Auto manufacturers may produce any combination of TLEVs, LEVs, ULEVs, and ZEVs as long as the fleet average requirement is met.

- Beginning in 1998, two percent of the vehicles produced and delivered for sale in California by the seven largest automakers were required to be ZEVs. That percentage increased to five percent in 2001 and ten percent in 2003.

In 1996 CARB eliminated the ZEV requirement from 1998 through 2002 while retaining the ten percent requirement for 2003 and beyond. In addition CARB directed its staff to enter into a Memorandum of Agreement with the seven largest automakers to participate in a Technology Development Partnership to accelerate the commercialization of advanced-battery vehicles by placing 3,750 demonstration ZEVs in California in 1998 through 2000. The automakers also committed to continued funding of ZEV-related technology research and development.

In November 1998 CARB amended its LEV regulations. The new amendments, known as LEV II, represent further emission reductions from motor vehicles. These standards extend the original LEV program from 2004 through 2010 with new requirements. The LEV II amendments affect passenger cars, light-duty trucks, and medium-duty vehicles. The main elements are:

- Extending passenger car emissions standards to heavier sport utility vehicles and pickup trucks (with gross vehicle weight up to 8,500 pounds) which formally had been regulated under less stringent emission standards;
- Extending and tightening of the fleet average emssion standards during 2004-2010;
- Creating a new super-ultra low emission vehicle (SULEV) category for light-duty vehicles;
- Significantly lowering of oxides of nitrogen emission standards for the low and ultra-low emission vehicle categories, a reduction of 75% from the current LEV standards;
- Increasing emission control durability standards from 100,000 miles to 120,000 miles for passenger cars and light-duty trucks;
- Further reducing of evaporative emissions; and
- Creating partial zero-emission vehicle (ZEV) credits for vehicles that achieve near zero emissions. (See Section Three of the report)

A biennial review of the CARB's Zero Emission Vehicle (ZEV) program is scheduled for September 2000. The purpose of the biennial review is to update the Board on progress being made towards meeting the ZEV program requirements. Staff to the Board will hold two workshops to present information related to the review and receive public comment for CARB's consideration.

At the first workshop, scheduled for March 29, 2000, staff will present preliminary information regarding the biennial review process, manufacturer status, current vehicle technology, and compliance with the Memoranda of Agreement. Staff will seek comment on the content of the preliminary staff assessment, and will invite comment on the experience of current EV drivers, and advances in ZEV drivetrains and other components. The preliminary staff assessment will be made available prior to the workshop.

At the May 31, 2000 workshop, CARB staff will present the draft Staff Report and Technical Support Document for the September Board meeting, with updated information on the topics referenced above, plus a discussion of costs, emission benefits, and the EV market. Staff will also present findings from an assessment of battery technology and manufacturing cost, currently being conducted by an external review panel.

Maine's Low Emission Vehicle Program

Under Section 177 of the Clean Air Act Amendments of 1990, states were allowed to adopt and enforce new vehicle standards which differ from the federal standards as long as such standards are identical to the California standards and are adopted at least two years prior to commencement of a model year.

Currently four northeast states have adopted the California Low Emission Vehicle program: Massachusetts (starting with model year 1996 motor vehicles); New York (starting with model year 1997), Vermont (starting with model year 1999), and Maine.

Maine adopted the California Low Emission Vehicle (LEV) standards on February 17, 1993, starting with model year 1996. However, legislation was subsequently passed stipulating that the effective date of the regulation was dependent on whether states in the northeast and the Ozone Transport Region also adopted similar rules. In December 1997, the Department notified the automobile manufacturers that the "triggers" had been met and that Maine's LEV program will start with model year 2001. This program includes California's Zero Emission Vehicle requirement.

In 1997, 38. M.R.S.A. Section 585-D was amended to require that "the commissioner shall complete a study of zero-emission vehicles and submit a report to the joint standing committee of the Legislature having jurisdiction over natural resources matters no later than January 1, 2000. This study must include an examination of zero-emission vehicle technology, price, performance and consumer acceptability and implementation issues relating to use of those vehicles in the State. The study must recommend any rulemaking necessary for the board to establish a zero-emission vehicle program that is appropriate for the State and a schedule that provides the automobile manufacturers with a minimum 2-year lead time prior to implementation of such a program. Any rules establishing a zero-emission vehicle program are major substantive rules pursuant to Title 5, chapter 375, subchapter II-A."

Section Three The Partial ZEV Program[1]

Partial ZEV Credit Program Overview

As mentioned above, the new partial ZEV program allows for and encourages the introduction of hybrid electric vehicles, reformer-equipped fuel cell vehicles, natural gas vehicles, and conventional gasoline vehicles with advanced emission control systems. These vehicles will be described in detail in Section Four of this report on technical feasibility. The partial credit scheme allows manufacturers to get credit towards the 10 percent ZEV mandate using these advanced technology vehicles. The credit system allows for credit to be taken in three different categories:

1) extremely low tailpipe emissions;

2) partial electric range capability; and

3) low emissions associated with processing the fuel used in the vehicle.

It is important to note that the partial ZEV credit program has one pre-requisite: all partial ZEVs must meet a tailpipe standard that is equivalent to the CARB certification level of a "Super Ultra-Low Emission Vehicle" or SULEV. This requirement ensures that all partial ZEV vehicles emit the same or less pollution than the power plant emissions that would be generated in re-charging a battery electric vehicle. The essential elements of the program are summarized below:

- A vehicle must meet baseline emissions criteria (SULEV tailpipe emissions);

- Each vehicle can potentially receive one ZEV credit if, and only if, it meets the baseline criteria, uses a clean fuel and can provide 120 miles of pure electric range;

- Vehicles that meet the baseline criteria, but not all of the others, will be limited to receiving less than one ZEV credit, even if the complete fuel cycle emissions associated with that vehicle are less than those of battery electric vehicles (BEVs);

[1] "parts of this section are excerpted from theCARB "LEV II and CAP 2000 Amendments Final Regulaory Order," 10/99

- Pure ZEVs must account for at least 40 percent of the 10 percent sales requirement.

Table 1 below compares advanced technology vehicles that are eligible for partial ZEV credit with ZEVs.

Table 1:
Comparison of ZEVs with Advanced Technology Vehicles

Advanced Technologies with Extremely Low-Emission or Zero-Emission Capability	Qualities in Common with ZEVs
Gasoline SULEV	Emissions comparable to EV-related power plant emissions and extended durability
Compressed Natural Gas SULEV	Same as above plus very low fuel-cycle emissions
Hybrid electric vehicle (HEV) with significant all-electric range	Partial zero-emission range
Methanol reformer fuel-cell vehicle[1]	Extremely low emissions
Direct methanol fuel-cell vehicle[1]	Extremely low emissions
Stored hydrogen fuel-cell vehicle[1]	ZEV
Battery-powered electric vehicle	ZEV

[1]Due to their inherent efficiency of operation, fuel cell vehicles can also result in reduced emissions of carbon dioxide, a greenhouse gas.

Determining Partial ZEV Credits

In the partial ZEV program a greater amount of credit is given to those vehicles that are closest to a true ZEV and a lesser amount is given for those vehicles that are closer to a conventional vehicle powered by an internal combustion engine. In the program, vehicles that have all of the characteristics of a ZEV (zero tailpipe and evaporative emissions; zero emissions associated with fuel refining; and all-electric driving range) are given one ZEV credit. Those vehicles that fulfill the minimum partial ZEV requirements and that have ZEV-like characteristics are given a fraction of one ZEV credit. The three ZEV-like characteristics that manufacturers can claim partial ZEV credits for (emissions, all-electric range potential; and emissions associated with fuel refining) are described below along with an explanation of how much credit can be taken for different ZEV-like characteristics. Manufacturers can claim up to 60 percent of the total ZEV mandate with partial ZEVs. The remaining 40 percent of the ZEV mandate must be fulfilled with true ZEVs.[1]

[1] The current program allows for 60 percent of the ZEV mandate to be fulfilled with partial ZEVs. CARB has scheduled a review of the ZEV mandate. At that time the program could be changed.

1) Emissions Standards

In order for a vehicle to receive any ZEV allowance, a vehicle would need to satisfy the requirements for receiving the "baseline ZEV allowance." To receive this allowance, the first requirement would be for the vehicle to at least meet the SULEV standard[2] at 150,000 miles and also satisfy applicable second-generation on-board diagnostics requirements (OBD II) and zero-fuel evaporative emission requirements. On-board diagnostics allow for the monitoring of engine and emission control components. Vehicles meeting the above requirements would receive credit equal to $1/5^{th}$ of a full ZEV credit. In other words, a manufacturer must sell five SULEVs to receive credit for one ZEV. Considering one compliance scenario for the ZEV mandate, if a manufacturer chose to fulfill the entire 6 percent of partial ZEVs with SULEV cars, 30 percent of annual car sales would have to be SULEVs. The emissions associated with this and other possible ZEV compliance scenarios are detailed at the end of this section.

2) All-Electric Range Capability

An additional allowance is provided based on the potential for realizing zero-emission vehicle miles traveled (VMT) (e.g. capable of some all-electric operation traceable to energy from off-vehicle charging), up to a maximum of $6/10^{th}$ of a ZEV credit. Many clean technologies, including some fuel-cell vehicles and hybrid electric vehicles, have the potential for zero emissions associated with some portion of the VMT. Under the revised ZEV program, such vehicles would receive a zero-emission VMT allowance, proportional to the estimated zero-emission VMT potential as a percent of total VMT which is the zero-emission VMT factor. To receive this credit, a manufacturer would need to provide an estimate of the likely zero-emission VMT potential of their particular vehicle design based on actual in-use data, an engineering evaluation of the vehicle's operational strategy and any other relevant information to validate the estimate.

zero-emission VMT allowance = 0.6 x zero-emission VMT factor

Some manufacturers have developed hybrid electric vehicle designs that deliver improved fuel economy but do not have any significant all-electric range (the Toyota Prius and Honda Insight for example). Such vehicles do not qualify for a zero-emission VMT allowance because without wall re-charging capability that provides significant all-electric range; such vehicles would not exhibit the lowest emission characteristics. However, even though these vehicles would not receive any zero-emission VMT

[2] Emissions from vehicles in this category are close to emissions associated with recharging electric vehicles in California. In the Northeast, power plant emissions associated with re-charging electric vehicles would be higher than in California due to the predominance of coal and oil burning power plants. Thus in the Northeast, SULEV vehicles will have lower emissions than true ZEVs assuming there is no deterioration in emissions over the life of the car.

allowance under this category, they could receive some allowance under a provision explained in the next section.

Some vehicles have potential for zero-emissions for one regulated pollutant (e.g., NOx) while having low-levels of emissions of other regulated compounds (e.g., non-methane organic hydrocarbons or NMOG). One such vehicle could be an on-board methanol reformer fuel-cell vehicle. This vehicle has virtually no NOx emissions since the operational temperature of the reformer is typically lower than the temperature required for NOx formation. Consequently, in order to credit such vehicles for zero-emission capability of a specific pollutant, CARB allows for this vehicle to receive a zero-emission VMT factor of 0.5.

Vehicles that do not have significant zero-emission VMT potential but are equipped with advanced batteries, an electric power-train, and other advanced ZEV technologies can qualify for a zero-emission VMT allowance of 0.1. This additional allowance is provided in recognition of the vehicle's contribution to helping develop advanced batteries and powertrains that assist in commercializing ZEV technologies. One such vehicle would be the Toyota Prius, assuming it is designed to meet the SULEV standard. The Prius is equipped with a limited number of advanced nickel metal hydride (NiMH) batteries and an advanced electric drive-train.

3) Emissions Associated with Fuel Refining and Distribution

Another characteristic that qualifies a vehicle to receive an additional ZEV allowance is the use of fuels with very low full fuel-cycle emissions to propel the vehicle. Under this proposal, a vehicle that uses fuel(s) with very low fuel-cycle emissions can receive a ZEV allowance up to a maximum of 0.2. The fuel-cycle emissions associated with a particular fuel are the total emissions associated with the production, marketing and distribution estimated as grams per unit of fuel. These emissions are then converted into grams/mile by applying the fuel-economy estimate of the vehicle. In order to receive this allowance, a manufacturer must demonstrate, using peer-reviewed studies or other relevant information that marginal NMOG emissions associated with the fuel used by the vehicle are lower than or equal to 0.010 grams per mile. It should be noted that for the purpose of providing this allowance, fuel-cycle NOx emissions are not considered in the determination since marginal NOx emissions for virtually all fuels are uniformly very low. Fuel-cycle emissions must be calculated based on near-term production methods and infrastructure assumptions. At this time, it appears that only gaseous fuels could very likely qualify for this allowance. Some liquid fuels, for example methanol, may also qualify with vehicle efficiency improvements and with the use of improved refueling evaporative controls.

If more than one fuel is used to propel a vehicle, then this ZEV allowance is awarded based on the percent of total vehicle miles traveled using fuel(s) with low fuel-cycle emissions. To illustrate, assume a hybrid electric vehicle with significant all-electric range uses off-vehicle charging electrical energy to propel the vehicle for 70 percent of the total VMT and another fossil fuel (e.g. gasoline) for the remaining 30 percent of the total VMT. In this case, only the off-vehicle electrical energy use meets the low fuel-cycle emission requirement. Consequently, the ZEV allowance awarded to this vehicle would be 70 percent of 0.2, which is equal to 0.14.

The partial ZEV allowance awarded to a specific vehicle, then, is the sum of the allowances earned by the vehicle including the baseline, zero-emission VMT and low fuel-cycle emissions. Table 2 summarizes partial ZEV allowances:

Table 2:
Partial ZEV Allowance Proposal

Characteristic	**Pre-requisite or optional requirement?**	**ZEV allowance**
Baseline allowance - Meets SULEV at 150K & 150K emission warranty	Pre-requisite for vehicles to receive any allowance	0.2
Zero-emission VMT allowance (1)(2)	Optional – qualifies vehicle for additional allowance	(0.6 x zero-emission VMT factor)
Low fuel-cycle emission allowance	Optional – qualifies vehicle for additional allowance	up to 0.2
Partial ZEV allowance		**Sum of the above**

The CARB program requires that 40 percent of the ZEV requirement be met by true ZEVs and vehicles that receive a ZEV allowance of one. This would serve to ensure sufficient production volumes of advanced battery electric vehicles, stored hydrogen fuel-cell vehicles or other non-emission vehicles that do not deteriorate. Maintaining this production requirement can help ensure continued technical development and pilot production process optimization and afford some economies of scale to help make these true zero-emitting vehicles affordable and more competitive in the 2005 to 2010 time frame.

Small and intermediate volume manufacturers have indicated that it would be cost-prohibitive for them to individually produce very low volume advanced technology true ZEVs in the foreseeable future, given the relatively small number of vehicles that would be required to meet 40 percent of the ZEV requirement. Consequently, in order to address this concern, CARB allows intermediate volume manufacturers to satisfy the 10 percent ZEV requirement using only partial ZEV allowances, if they choose to do so.

Under this program, qualifying technologies receive an allowance ranging from 0.2 ZEV credit to multiple ZEV credits depending on their emission characteristics, use of

advanced technologies to make vehicles that are more acceptable to consumers and other factors. The program provides manufacturers the flexibility to produce vehicles qualifying for ZEV credit that they envision would be most successful in the market place and would best meet consumer expectations. Overall, the program allows considerable flexibility to manufacturers, incenticize new near-term zero-emission technologies, and maintain the true ZEV development efforts -- eventually yielding more near zero emission reduction options than might otherwise be achieved.
Table 3 provides examples of advanced technology vehicles and the partial ZEV credits or allowances that would be earned from their ZEV-like characteristics.

Table 3:
Examples of Partial ZEV Allowance Calculation

Technology/Manufacturer	Baseline Allowance	Zero-emission VMT allowance	Low fuel-cycle allowance	**Partial ZEV allowance** [3]
Gasoline SULEV	0.2	0.0	0	**0.2**
Hybrid gasoline SULEV with no all-electric range (AER), equipped with advanced Batteries, electric powertrain	0.2	0.1	0	**0.3**
CNG SULEV	0.2	0.0	0.2	**0.4**
Gasoline Hybrid SULEV w/ 20-mile AER, off-veh. recharging	0.2	0.3	0.1	**0.6**
On-board methanol reform. Fuel Cell (FC) vehicle	0.2	0.3[1]	0.2[2]	**0.7**
Hybrid SULEV with NIMH bat. (60 whr/kg) and 100-mile range.	0.2	0.6	0.2	**1.0**
On-board hydrogen FC vehicle w/ off-board partial oxidation reforming of hydrogen using fuel with low fuel-cycle emiss.	0.2	0.6	0.2	**1.0**

1) Assumes on-board methanol reformer produces virtually no NOx emissions
2) Assumes methanol has very low fuel-cycle emissions
3) Partial ZEV allowance= Baseline allowance + Zero-emission VMT allowance + Low fuel-cycle allowance

California Equivalent Low Emission Vehicle (EZEV) Standard

The California Air Resources Board (CARB) amended the LEV program to add a new equivalent zero-emission vehicle (ZEV) emission standard. This new standard is based on California in-basin power plant emissions of NOx and reactive organic gases (ROG) associated with charging battery-powered electric vehicles. Vehicles certifying to the EZEV standard would need to demonstrate exhaust, evaporative and refueling emissions that, in combination, fall below the EZEV certification standards. Vehicles certified to the EZEV standard would be credited toward a manufacturer's ZEV requirement on a one-to-one basis. The certification standards for non-methane organic gas (NMOG), NOx, particulate matter (PM), and carbon monoxide (CO) are:

Table 4:
EZEV Certification Standards Compared with ULEV Certification Standards

Pollutant	ULEV standard (Grams per mile)	EZEV Emissions Level (Grams per mile)
NMOG	0.040	0.004
NOx	0.2	0.02
PM	--	0.004
CO	1.7	0.17

Section Four States Adoption of the California ZEV Program

Section 209(a) of the Clean Air Act prohibits states from adopting or attempting to enforce "any standard relating to the control of emissions from new motor vehicles." There are two exceptions: (1) California may adopt more stringent standards after receiving a federal waiver (section 209(b)), and (2) other states may adopt the California vehicle emissions standards as long as the standards are identical to those in California (section 177).

As a means of attaining the federal health standards for ozone, Massachusetts and New York adopted the California LEV program with the ZEV mandate in the early 1990's. In the spring of 1996, California repealed its ZEV mandate from 1998 to 2002, leaving in tact the ten percent sales requirement in 2003. Simultaneously, CARB and the car makers signed private contracts, referred to as Memoranda of Agreement (MOAs), which require the manufacturers to produce for sale 3,750 advanced battery electric vehicles from 1998 to 2000.

Several months later, Massachusetts amended its LEV regulations to scale back the ZEV mandate to 3,750 ZEV from 1998 to 2000 in order to maintain a program that is identical to California, as required under section 177. In New York, the mandate was left as the original California program.

In 1997, the Second Circuit Court of Appeals ruled that the New York program could not be adopted. In Massachusetts, the court asked for EPA's opinion on whether or not the California ZEV mandate is a "standard" rather than an enforcement action. The US EPA opinion was recently summarized in a letter to the First Circuit Court of Appeals. EPA's opinion is that the Massachusetts' zero emission vehicle (ZEV) mandate is a "standard" and not preempted under the Clean Air Act. Specifically, the Agency found that the ZEV mandate is an integral part of the California Low Emission Vehicle (LEV) program subject to the identicality restrictions of the Act. In addition, the Agency found that the provisions of the MOAs[3] should be considered standards since they grew directly out of the ZEV regulatory requirements and were intended to stand in their place and serve the same function. If adopted by the First Circuit in its ruling on the Massachusetts ZEV case, EPA's decision means the following:

- The largest automobile manufacturers[4] must produce for sale up to 3,750 ZEVs in Massachusetts by 2000, or pay a penalty for each vehicle not delivered for sale.

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[3] The Memorandums of Agreement (MOAs) are private contracts between California and each of the seven largest automobile manufacturers. A possible purpose of placing the ZEV requirements in private contract rather than regulation was to prevent the Northeast states (e.g., New York and Massachusetts) from requiring the car makers to produce ZEVs in the Northeast.

[4] GM, Ford, Daimler-Chrysler, Toyota, Honda, Nissan.

- Any state adopting the California LEV program within the jurisdiction of the First Circuit must also adopt the ZEV mandate.

- EPA's decision on the legal status of the ZEV mandate is likely to persuade other federal appellate courts seeking to rule on this issue.

- California is unlikely to enter into another MOA with the automakers since such an action is not likely to prevent other states from adopting its provisions as if they were in regulation.

A final decision from the court is pending on the Massachusetts ZEV mandate.

It is likely that as a result of the anticipated First Circuit Court of Appeals decision and the U.S. EPA decision, states that adopt the California LEV II program will also adopt the ZEV mandate. As a result, all Northeast states that are participating in the California Low Emission Vehicle (LEV II) program (some states have adopted the LEV program without the ZEV mandate) will receive between 15 and 25 percent of new vehicles sales as advanced technology vehicles starting in 2003. For example, under certain reasonable assumptions, Massachusetts may expect to receive about 2,000 all-electric-range EVs, about 20,000 hybrid electric vehicles, and 30,000 gasoline or natural gas-powered SULEVs with zero evaporative emissions in 2003 under LEV II. This large number of Advanced Technology Vehicles (ATV) may be expected to provide significant air quality benefits to participating LEV II states, and place the Northeast at the forefront of automotive technology advancement.

Northeast States Adopting the ZEV Mandate

Assuming that the First Circuit adopts EPA's rationale, and other federal courts find EPA's decision persuasive, this decision effectively eliminates the threat of another MOA that might have placed all or part of the LEV II ZEV mandate out of reach of the Northeast states. The LEV II ZEV mandate is likely to become effective in Massachusetts, New York, Vermont and Maine. Under its provisions, it is likely that in the early years (2004-2007), car makers will produce about 1 percent of their fleet as all-electric-range EVs, and about 15 to 20 percent of their fleet as a mixture of gasoline-powered SULEVs and hybrid electric vehicles. These vehicles must meet the requirements of a partial ZEV: zero evaporative emissions, 150,000 warranty, and emissions comparable to an EV charged off the California power grid.[5]

The partial ZEV credit scheme results in significant numbers of vehicles for participating northeast states. For instance, Massachusetts might expect about 20,000 hybrid-EVs, and New York might expect about 40,000, under certain conditions (see Table 6 below.) For comparison, the seven largest automakers have only leased several

[5] As noted earlier, California utilities are far cleaner than the Northeast power grid, especially for NOx.

hundred EVs in California since 1997. In total, the partial ZEV credit requirement may require a large portion of new vehicles sales (20-25 percent) to meet SULEV standards with gasoline, natural gas, hybrid electric, or fully electric vehicles. The air quality benefits associated with these very low emission standards, and the lack of deterioration and fuel efficiency of electric vehicles, are not insignificant.

Table 6:
Possible Compliance Scenario for ZEV Mandate (2003+)

State	1995 New Car Registrations	Pure ZEVs (4%)	Partial ZEVs Hybrids (10%)	Partial ZEVs SULEVs (15%)
Massachusetts	203,806	8,152	20,380	30,450
Maine	29,438	1,177	2,943	4,410
Vermont	19,121	764	1,912	2,865
New York	491,434	19,657	49,143	73,710

Table 6 provides a possible compliance scenario with the ZEV mandate. The scenario assumes that the ZEV mandate will require four percent of vehicles to be pure ZEVs. It is also important to note that only light duty vehicles, and not sport utility vehicles (SUVs) and trucks heavier than 3,750 lbs. are included in the estimate since the ZEV mandate only applies to lightest vehicles. Thus, while the number of cars and trucks registered in Maine was approximately 50,000 in 1995, only the light duty portion, approximately 29,000 was used for this calculation.

For the purpose of this analysis, it is assumed that carmakers would meet 60 percent of the ZEV mandate with partial ZEVs. Honda's Z-LEV technology for gasoline vehicles and the current auto maker interest in hybrids led to the conclusion that gasoline-SULEV and hybrids will dominate the partial ZEV credit market from 2004 to 2011. Up to five SULEVs must be produced for sale to generate one ZEV credit (depending on whether they have other ZEV-like characteristics). As was shown in Table 4 a "no all-electric-range" hybrid electric vehicle will generate .3 ZEV credits, thus it takes 3.3 hybrids of this type to generate one ZEV credit. Assuming an even split between SULEV and hybrid partial ZEV vehicle types, carmakers must produce 15 percent SULEVs and 10 percent hybrids starting in 2004 for a total of 25 percent of new vehicle sales.

Section Five   Technical Feasibility

In 1995, the only electric vehicles for sale in the U.S. were "conversions" of regular gas cars, there were no hybrid-electric vehicles available, and fuel cells were barely being discussed. Today, all the major automakers have made electric vehicles available, with over 3,300 EVs produced by the major auto manufacturers on the road in the U.S.; Toyota has sold over 30,000 of its hybrid-electric sedan, the Prius, in Japan and is bringing it to the U.S. this year; Honda is already selling a hybrid vehicle, the Insight, in the U.S.; and all of the major car companies have made large investments in fuel cell technology, with commitments to introduce fuel cell cars by 2010 or earlier.

Much of the focus of this clean vehicle technology development has been in California, New York and Massachusetts, the ZEV mandate states. As automakers continue to develop and promote clean cars, it seems likely that they will focus their efforts on those areas of the country where they receive incentives or must fulfill regulatory obligations. This "Technical Feasibility" section reviews the clean, advanced vehicle technologies currently available and those that will likely become available within the ZEV mandate time frame.

Battery Electric Vehicles

Electric vehicles are the only cars available that have no tailpipe emissions. EVs are already available in the U.S. -- primarily, but not exclusively, in those states that have a ZEV mandate. Most of the major automakers currently offer EVs for sale or lease, as do some smaller manufacturers including Massachusetts-based Solectria.

Definition

A battery electric vehicle is one that uses an electric motor powered by a battery pack, instead of using an internal combustion engine. The California Air Resources Board has designated the battery EV as the only car currently to meet CARB's zero emission vehicle classification, which requires that the car have no tailpipe emissions, no evaporative emissions, no emissions from gasoline refining or sales, and no on-board emission control systems that can deteriorate over time.

Like the hybrid, an electric car is equipped with regenerative braking, which allows it to recapture braking energy. Since, unlike a hybrid, an EV does not use a gas engine, it must be equipped with a fairly large battery pack, depending on the type of battery used and the weight of the vehicle. There have been significant advancements in battery technology over the past 5 years, in part due resulting from a federal/industry partnership known as the U.S. Advanced Battery Consortium. Initially, most EVs were equipped with lead acid batteries; today, they are more likely to use nickel metal hydride batteries, as well as other advanced battery technologies (See below for more discussion of battery technology).

Performance

Any potential EV driver should be aware that current EV technology does not provide performance comparable to gas cars. However, EVs can easily meet the range needs of many daily commuters and fleets. For example, lead acid powered EVs typically can travel between 50 and 70 miles on a single charge. According to the U.S. Department of Transportation, the average daily commute, round-trip, is 22 miles and the average shopping trip is 10 miles, round-trip - both well within the typical EV range. EVs are also viable in fleet applications where the vehicles drive relatively short routes. And, EVs equipped with the more advanced nickel metal hydride batteries can have up to twice as much range, although the range will differ significantly for different types of vehicles.

Developments in Battery Technology

Battery technology is the biggest factor in making EVs commercially viable - both in terms of providing range comparable to a gas car and in making EVs affordable. Because of its importance, battery development has received large investment from industry and the government over the past 10 years. The results have been significant advancements in the technology. Five years ago, most EVs were powered by lead acid batteries, which, depending on the weight and efficiency of the car, provided from 50 to 70 miles of range on single charge. Most EVs today are powered by "advanced" batteries, such as nickel metal hydride or lithium ion batteries. This translates into longer range and the ability to power larger vehicles with batteries. For example, the electric versions of the Ford Ranger, Chevy S-10 and Toyota RAV-4 all use nickel metal hydride battery packs. Lithium ion is another leap in battery technology. Nissan equipped its electric sedan, the Altra, with lithium ion batteries, giving it a real world driving range of up to 100 miles.

The following is a quick look at the range offered by each of the major EVs being offered today:

VEHICLE	BATTERY	DRIVING RANGE
GM EV1	Lead Acid	50 – 70 miles
GM EV1	Nickel Metal Hydride	80 – 120 miles
Chevrolet S-10	Nickel Metal Hydride	50 – 70 miles
Honda EV Plus	Nickel Metal Hydride	70 – 90 miles
Ford Ranger	Nickel Metal Hydride	50 – 70 miles
Toyota RAV4	Nickel Metal Hydride	60 – 80 miles
DaimlerChrysler EPIC	Nickel Metal Hydride	70 – 80 miles
Solectria Force	Lead Acid	50 miles
Solectria Force	Nickel Metal Hydride	80 – 100 miles
Nissan Altra	Lithium Ion	60 – 80 miles

Information courtesy the California Air Resources Board and EV America

Cold Weather Driving

One of the primary EV performance issues is cold weather driving. Low temperatures can have a negative effect on the EV battery pack and, therefore, the vehicle range. In addition, cold weather conditions create operational inefficiencies for all types of vehicles, resulting in increased on-road energy consumption. The Vermont Electric Vehicle Demonstration Project, conducted by EVermont, explored the issue of cold weather driving and concluded that EVs equipped with proper thermal management systems can operate effectively even in extreme low temperatures. The project tested three Solectria Forces, equipped with nickel metal hydride batteries, driving the vehicles during warm and cold weather in Vermont and Canada. Initially, the demonstrations showed that the range of the nickel-metal hydride EVs is reduced to about 65% of that during moderate temperatures. By comparison, a regular gas car's range is reduced to approximately 80%. However, with appropriate cabin and battery thermal management, the study concluded, a NiMH EV can increase the range by about 23%.

Infrastructure[7]

EVs must be plugged in to recharge the batteries. Right now, there are still two different charging options being used by automakers -- this is one area that is not "standardized" across the electric vehicle market. One charging option is called "conductive" charging. Conductive charging systems use a plug and cord system which can vary by the type of connector used and the level of voltage and current. The

[7] Charging information courtesy the Electric Vehicle Association of the Americas

other option is "inductive" charging, which uses a special "paddle" that transfers energy to the vehicle by means of magnetic induction.

Both types of systems may require special electronics off the vehicle, although it is possible for some conductive charging to be done on a regular household outlet. For example, Solectria's EVs simply require a standard 220 volt outlet, such as would be used for large household appliances like a clothes dryer. The length of time for a recharge depends on the battery. But, in general, an EV would require a minimum of two to three hours of charging at the 220 level, and possibly as much as eight hours, making this option best for overnight charging at home or daytime charging at the workplace. Fast charging technology has been developed that can dramatically reduce the charge time. This method uses a high-powered system that can provide a full charge in as little as ten minutes

With regard to the cost of charging an EV, the Electric Vehicle Association of the Americas has said that, while costs will vary depending on the time of day you charge the vehicle, your utility rates, and the type of EV you drive, it is almost certain that an EV driver will pay substantially less than the cost of refueling a gas car. The average monthly fuel cost for a typical EV driver is expected to be less than $15, compared to $50 for gasoline. As with gas cars, the heavier the car and the more aggressively it is driven, the lower the fuel economy will be.

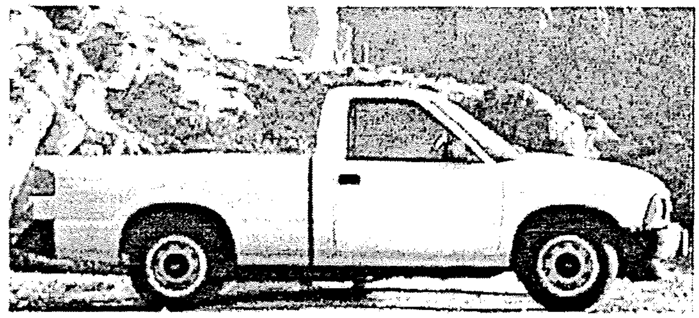
Emissions

EVs are the only vehicles currently available that offer zero emission operation, emitting no pollutants and no carbon dioxide. Even when taking into account the emissions associated with producing the electricity to charge the vehicle, EVs come out ahead. The primary reason for this is that electric motors are three to four times as efficient as traditional internal combustion engines. In addition, power plants are required to meet more stringent emission standards than motor vehicles and, unlike motor vehicles, have maintenance performed by professionals, as well as routine government oversight and emissions testing. Pollution is easier to control from a few power plants than from millions of cars. Finally, EVs will become even cleaner as the electric utility industry moves more toward clean, renewable energy sources.

Availability

As already noted, there are quite few EVs available in the U.S. Most of them are offered in California and the Northeast.

Chevrolet S-10: GM has developed an electric version of its Chevrolet S-10 Pickup for the fleet market. GM put a 114 horsepower, AC Induction Motor and Delco lead acid battery pack into a standard S-10 pickup, using the same

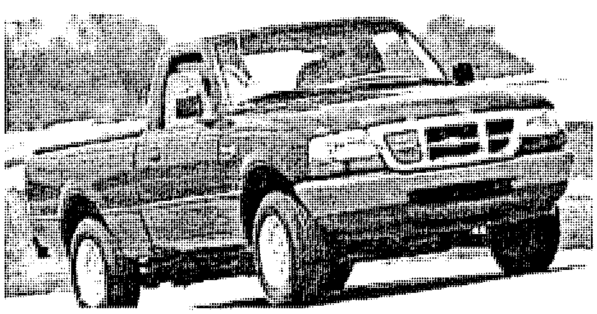


frame, chassis and suspension found in the gas-powered S-10. The electric version is available in a regular cab configuration with a short box and two-wheel drive. It has a payload of 950 lbs and was designed to meet the demands of commercial fleet operations.

With the lead acid battery pack, the S-10 has an effective range of 40 – 60 miles, depending on weather and road conditions and how the car is driven. The battery can be fully recharged in just 10 minutes using a Magne Charge Inductive Fast Charger. With regular inductive charging, it takes 2 – 3 hours. A fully charged S-10 Pickup Electric accelerates 0-50 mph in 10.3 seconds, 13.5 seconds at 50% charge. The S Pickup Electric features standard front-wheel drive, anti-lock brakes, a driver's side air bag, daytime running lamps and air conditioning.

The electric S-10 is available to fleets for $32,995. Since the S-10 became available in late 1996, approximately 490 have been sold.

For more information on the S-10, go to www.gm.com/vehicles/innovations/chevys10.html



Ford Ranger: The other battery-powered pickup available today is the Ford Ranger EV, an electric version of Ford's compact truck. The Ranger EV uses a 90 horsepower AC induction motor. It comes equipped with either lead acid batteries or advanced nickel metal hydride batteries. The lead acid batteries give it a range of about 50 miles, with an electronically controlled top speed of 78 mph. In 1999, Ford began offering the NiMH battery powered version, which has an 80 mile range. It takes about 6 – 8 hours to fully recharge the batteries using an on-board conductive charger.

The lead acid Ranger is available for $34,999, or a $349 monthly lease. The nickel metal hydride version is available for $48,995 or a $614 monthly lease.

For more information go to wwwu.ford.com/electricvehicle/ranger.

Toyota RAV4: Currently, the only electric SUV available is the Toyota RAV4-EV. After testing the electric RAV4's in Japan and the U.S., Toyota began marketing them in the U.S., primarily to fleets and primarily in New York and California, in 1997. Although it is based on an existing gas-powered vehicle, the 5-passenger RAV4-EV is not actually a conversion. It was engineered from the ground up to be an electric car.

RAV4 EV: Think of it as a socket rocket

The RAV4-EV uses a 50 kW, 67 horsepower permanent magnet motor and a nickel metal hydride battery pack. This gives the car a combined city/highway driving range of approximately 125 miles, although the range varies in different weather conditions. The top speed is governed at 78 mph and its payload is around 827 lbs. It uses an inductive charging system, which, until recently, was on board the vehicle. Toyota has also unveiled a new model of the RAV4 with an off-board charger, helping to lower the vehicle weight. It takes 6 – 8 hours for full recharge of the batteries.

The RAV4-EV is currently available only in California, Massachusetts and New York. Toyota is targeting fleet users who are willing to buy or lease a minimum of 10 vehicles. The price of the new RAV4 $44,222. Since the car's introduction in 1997, 636 RAV4-EVs have been sold or leased in the U.S..

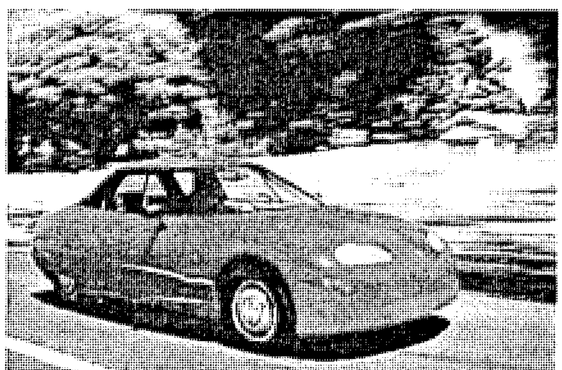
Daimler Chrysler EPIC: As the biggest seller in the minivan market, Daimler Chrysler chose to develop an electric minivan based on the 1999 Dodge Caravan. Dubbed the EPIC, it's the only electric minivan being produced today. The EPIC is powered by a 100 horsepower, AC induction motor and SAFT nickel metal hydride batteries. The NiMH battery pack gives the van a range of about 96 miles in combined city/highway driving. The range is likely somewhat less in cold weather.

This is a heavy vehicle – 5800 lbs. GVW – with a 925 payload, so it takes 17 seconds to accelerate from 0 – 60 mph. As with many EVs, the top speed is governed at 80 mph. It uses an off-board conductive charger which recharges the EPIC in five hours. The EPIC is also capable of taking a "fast charge" which lowers the charge time to only 30 minutes.

The EPIC is available to fleets in California and New York for $450/month for a three-year period. The off-board charger is included in this price.

The EPICs were manufactured on the same production line that builds the Dodge Caravan. In February 1999, 120 were placed on dealers' lots in California for lease by interested fleets; over 75 have been leased (25 in New York). In February of this year, DaimlerChrysler delivered 45 electric EPICs to the U.S. Postal Service in San Diego.

General Motors EV1: The GM EV1 was the first production electric vehicle by a major automaker to be made available in the U.S. A two-seater with a distinctive tear-drop shape, this vehicle was designed to be a showcase for GM's electric vehicle technology. Although clearly not intended as a family or fleet car, the EV1 delivers high performance and comfort. GM just introduced a new version of the EV1 – Generation II (Gen II). Gen II is powered by a 137 horsepower, 3-phase AC induction motor and according to GM, the new drive system is half the size and cost of the first generation of EV1. Gen II will have two battery options: a nickel-metal hydride (NiMH) battery pack or a new, advanced lead-acid battery pack. GM reports that the NiMH pack will give the EV1 a real-world range of 75 – 130 miles, depending on temperature, terrain and how the car is driven. The advanced lead acid batteries give the car an estimated 55 – 95 mile range, a 20 – 30% improvement over the 1997 EV1. The EV1 uses inductive charging, which requires a special off-board 220-volt charger (the price is included in the total lease price). The new lead acid batteries will recharge from 20% to 80% in 2 or 2.5 hours; total recharge (from 0 – 100%) takes about 5.5 to 6 hours. It takes six to eight hours for a charge from zero to complete for the NiMH batteries. It is not clear yet whether the batteries can be "fast-charged", which could reduce the full charge time to one hour.



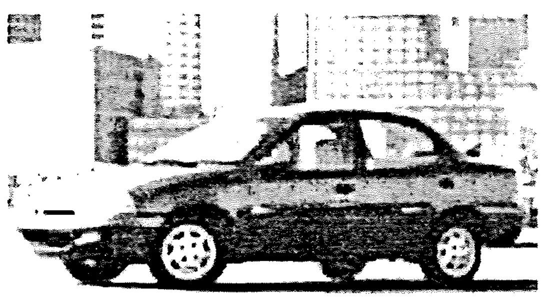
The EV1 was designed and built "from the ground up" to be an EV, so it was designed to be far more efficient than standard gas cars. The space frame is made of aluminum, the body panels from composite plastic. According to GM, the EV1 is the most aerodynamic and energy-efficient vehicle in the world today. This translates into high performance for an EV -- the EV1 accelerates from 0 – 60 mph in 8.5 seconds – faster than many gas cars.

The EV1 is available for lease only in California and Arizona. This is because of the advantageous climate conditions; tax and other incentives that draw down the lease price; and, of course, the need to fulfill California's ZEV mandate. However, the EV1 is also available to "select fleets". For example, Georgia Power has 26 EV1s and will be acquiring more as part of a program to make the cars available to employees.

The lease price for the new advanced lead acid EV1 is $33,995, which translates into a monthly lease payment $574. This price drops down to $424 in some parts of California thanks to federal and local tax incentives. The NiMH version costs $43,995 to lease. Since its introduction in December 1996, the EV1 has reached sales of 591 units.

For more information go to www.gmev.com.

Solectria Force: Since the first Force was sold in 1991, Solectria has sold roughly 200 of these electric sedans. It is a production "conversion" vehicle, available with lead acid, nickel metal hydride or nickel cadmium batteries. The lead acid version has a range



of approximately 50 miles; the NiMH version range is 100 miles; and the nickel cadmium version goes approximately 85 miles on a single charge. The Force has been used extensively in cold weather testing and is used by fleets and individual drivers throughout New England. It is available across the United States. Pricing information is available only from Solectria.

The Maine Electric Vehicle Project currently "shares" a 1995 Solectria Force.

For more information, go to www.solectria.com

Hybrid-Electric Vehicles

Currently, hybrid-electric vehicles are the advanced technology vehicles receiving the biggest marketing "push" from automakers. The hybrids being shown today combine an electric motor with a gas or diesel engine to significantly increase fuel efficiency and lower emissions. Honda and Toyota are already selling hybrids: Toyota introduced the *Prius* in Japan in December 1997, and Honda launched the Insight in the U.S. in December 1999. Sales of the Prius in Japan have topped 30,000 units; in fact, monthly production had to be ramped up to meet the unexpectedly high demand. Now, other major automakers, including General Motors, Ford and DaimlerChrysler, are issuing public commitments to introduce hybrid vehicles to the U.S. market.

Definition

What exactly is a hybrid-electric vehicle? A hybrid-electric vehicle, or hybrid, has two sources of motive energy on board the vehicle. The combination of a diesel or gas engine with an electric motor is what most passenger hybrid vehicles use today - it's found in the Prius and the Insight, as well as two prototype hybrids unveiled recently at the Detroit Auto Show. A hybrid could also combine other elements such as a gas turbine, ultracapacitor or flywheel; however, this report will speak only to the electric motor/gas engine combination that will drive hybrids coming to market in the next few years.

The benefits of a hybrid system are better mileage, lower emissions, ease of use, and performance comparable to regular gas cars. How these different benefits stack up depends on how the hybrid system is configured. There are numerous ways to design a hybrid system, and, thus far, automakers are each developing slightly different systems that trade-off the costs and benefits differently. There are three general categories for a hybrid configuration:

- A hybrid can use the electric motor only as an assist to the gas engine;
- It can use both the electric motor and the engine to power the wheels; and
- It can use only the electric motor to power the wheels, with the gas engine serving to supply energy to the motor or battery.

With hybrids that use the electric motor to assist the engine, the motor typically kicks on only when the car starts from a stop, during rapid acceleration, or on steep climbs. The key advantage of the hybrid system in this configuration is that it allows the car to utilize regenerative braking. With regenerative braking (regen), energy normally lost during braking can be recovered and stored in the battery. This is not an insignificant amount of energy: in city driving, a gas car loses approximately 30% of the engine output during braking. With this hybrid, the small battery pack is constantly recharged during driving, either through regen braking or by the engine. This means the car doesn't have to be plugged in. In essence, this hybrid is designed to provide the performance of a gas car with lower emissions and higher fuel economy. However, this car never achieves zero emission operation. The Honda Insight is an example of this type of hybrid (see description below under *Availability*.)

Another type of hybrid uses both the electric motor and the engine to drive the wheels. This arrangement allows greater flexibility in responding to driving conditions. At a stop, the engine may shut off, eliminating idling emissions. The electric motor may work alone at low speeds, allowing the vehicle to be zero emission in neighborhoods or urban areas, for example. The engine will take over at higher speeds, when more power is needed. Typically, these cars use a relatively small battery pack and are not plugged in; the engine recharges the batteries while the car is in operation. The Toyota Prius is an example of this type of hybrid (see description below under *Availability*).

Hybrids that use only the electric motor to drive the wheels (often called a series hybrid) are not being developed by the major automakers for commercial introduction at this time. This type of hybrid only uses the gas engine to supply energy to the battery or to the electric motor. This means the gas engine can operate steadily at an optimal speed, making it more fuel-efficient. Also, the gas engine can be shut off for zero emission operation. This type of hybrid can be plugged in, which translates into greater reductions in pollutants and CO2 emissions reductions, especially if the electricity is being generated by non-fossil fuel sources. However, the major automakers are focusing their efforts on hybrids that do not need outside recharging in order to make the users' experience of the hybrid "transparent".

Performance, Infrastructure and Emissions

Performance

As noted above, hybrid vehicle performance is quite comparable to that of a regular gas car. The Toyota Prius, for example, accelerates from 0 - 60 in 12 seconds (by comparison, the MY 2000 Camry gets from 0 - 60 in 11.1 seconds) and has a maximum speed of 100 mph. Honda says the Insight's acceleration is comparable to that of an ordinary gas car with a 1.5 liter, 4-cylinder engine.

Test Driving the *Prius* and *Insight*

Both Honda and Toyota have provided journalists the opportunity to test drive their respective hybrids. Articles reporting on these journalists' impressions are attached to this study. The following are a few sample quotes from these articles:

"After several days' driving in "real" traffic conditions, including motorways ... the car patently makes its own case."
Financial Times, 10/9/99

"The Insight makes a convincing demonstration. The car moved easily in the flow of high-speed commuter lane traffic on Interstate 93 just outside Boston on a recent week-long test drive. When the digital speedometer read 75 miles per hour, a moving bar graph just below the speedometer indicated the car was getting 42 miles per gallon of gasoline."
Boston Globe, 12/6/99

Since hybrids such as the Prius and the Insight do not rely primarily on battery power, they would seem to offer no special concerns for cold weather driving.

Infrastructure

Neither the Prius nor the Insight needs to be plugged in. Drivers simply fill up the gas tank as usual. All of the major automakers have indicated their intent to develop hybrids that do not use off-board charging.

Emissions and Fuel Economy

The Honda Insight meets California's Ultra Low Emission Vehicle standard. Toyota is developing an U.S. version of the Prius that will meet the Super Low Emission Vehicle standard.

Both the Honda Insight and the Prius have mileage ratings about twice that of comparable cars. However, depending on how the hybrid is designed, the fuel economy savings may differ

Availability and Cost

As has already been discussed, Toyota and Honda are the first auto manufacturers to offer hybrids in the U.S. The Honda *Insight* went on sale last December, and the *Prius* will be available sometime around mid-2000. Toyota plans to sell about 1,000 units per month at a base sticker price of $18,800. Honda has said they only plan to make 4,000 to 5,000 *Insights* available.

Toyota Prius The Toyota Prius is the first mass-produced hybrid-electric vehicle. The 4-door, 5-passenger sedan is equipped with a 1.5 liter, 4-cylinder engine, an electric motor, and a nickel-metal hydride battery pack. A complex onboard computer system determines whether the car is being propelled by the gas engine, the electric motor or the two in combination. When starting out, at low speeds and while idling, the electric motor alone drives the car. At higher speeds, the gas engine kicks in, with the electric motor providing an assist during acceleration; the electric motor shuts off entirely during highway driving. The batteries are recharged by the gas engine and by regenerative braking, so the Prius does not require plug-in charging.

According to Toyota, the Prius achieves 55 mpg in the U.S. combined driving cycle. Toyota also reports that the Prius reduces emissions of nitrous oxides and carbon monoxide by 90%, and cuts hydrocarbon emissions by 75-90%, qualifying the car as a SULEV.

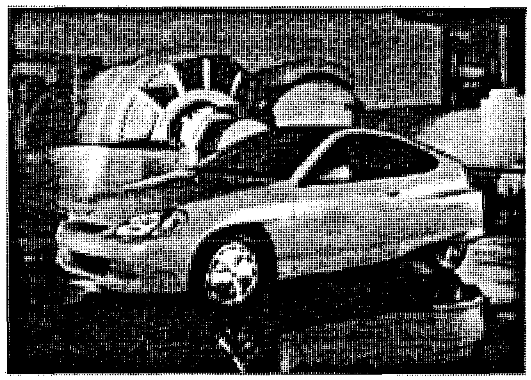
Toyota plans to price the Prius at under $20,000 when it brings the car to the U.S. market in mid-2000.

More information on the Toyota Prius can be found at http://www.toyota.com/afv/prius/intro_prius.html

Honda Insight *Honda* launched its hybrid-electric Insight in the U.S. last December – the first Insights were delivered in California; Northeast dealerships received delivery in January. The compact two-seater topped the EPA's fuel economy list for model year 2000 cars with a mileage rating of 61 mpg in city driving and 70 mpg on the highway. With its 10.6 liter gas tank, this mileage means the Insight can travel from 600-700 miles on a single fill-up. The comparably sized Civic gets about half that – 28 mpg in the city, 35 mpg on the highway. As for other emissions, the car meets California's ultra-low-emission vehicle (ULEV) standards.

The Insight's high fuel economy is as result of both the hybrid-electric powertrain and an extremely lightweight aluminum body. The car runs primarily on gasoline, with an electric motor that assists during acceleration and recharges the batteries during braking and deceleration – energy lost as heat and friction in regular gas cars. The electric motor means the gas engine is significantly scaled down –a 1.0 liter, 3-cylinder engine, as opposed to the similarly sized Civic's 1.6 liter engine. The vehicle's nickel-metal hydride battery pack is continuously recharged during driving, so, like the Prius, the Insight does not require off-board charging.

The Insight's MSRP is $18,880 or $20,080, depending on whether the car is fully loaded. Honda only plans to sell between 4,000 and 5,000 units of this car. Thus far, demand has outstripped production of the Insight. Honda dealers have taken advance orders for over 200 Insights. Honda plans to ramp up production to 300 units per month soon.



Information on the Honda Insight can be found at http://www.honda2000.com/models/insight/index.html

DaimlerChrysler Durango Late last year, DaimlerChrysler unveiled a hybrid version of it. Dodge Durango. In yet another variation on the hybrid drivetrain, the hybrid Durango is equipped with an electric motor that powers the front wheels, while 3.9-liter V6 the engine drives the rear. The addition of the electric motor means hybrid Durango will have the same power, acceleration and performance provided by a conventional V8 engine Durango. The hybrid SUV gets 18.6 mpg, compared to 15.5 mpg of the regular Durango -- a 20% improvement. DaimlerChrysler announced that this version of the Durango would cost $3,000 more the conventional Durango; however, the company used the Durango unveiling to urge Congress to pass a $3,000 tax credit for hybrids and said they would not introduce the Durango without such a purchase incentive.

General Motors Hybrid-Electric Pickup In 1999, GM announced that it would be deploying a small fleet of hybrid-electric pickup trucks in New York and California in 2000. Although the company provided few details, a GM spokesman said GM planned to test 10 Chevrolet Silverado and GMC Sierra pickups equipped with both a gas engine and an electric motor with a lead acid battery. These vehicles will be placed into GM's own

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Future Outlook There seems to be a consensus in the automotive industry today that hybrids will be the primary electric alternative to gasoline vehicles in the immediate future. Ford Chairman William Clay Ford Jr. recently said that he thinks hybrids will comprise 20% of vehicle sales by 2010. Robert Bienenfeld, Manager of the Alternative Fuel Task Force at American Honda Motor Company was recently quoted on CNN.com saying that, in the next 5 - 10 years, virtually every automaker will probably come to market with a hybrid.

Under a federal initiative called the Partnership for a New Generation Vehicle (PNGV), the U.S. Big Three have all committed to introducing 80 mpg cars by 2003; hybrids are the designated technology for reaching this mileage goal in the near term. The autos are required to present demonstration cars this year, and, at the January Detroit Auto Show, both GM and Ford showed their PNGV prototypes. The five-passenger Precept uses a diesel engine and electric motor to achieve approximately 80 miles per gallon. The car body is made with lightweight aluminum and plastics, as is the Ford Prodigy. The five-passenger Precept gets 70 mpg with gasoline, and 80 mpg with diesel. Both automakers have said these cars will not advance to production models. Rather, they are working prototypes to test and demonstrate hybrid technology.

In February, DaimlerChrysler just unveiled its PNGV prototype, a hybrid version of the Dodge ESX3 sedan. The ESX3 uses a 1.5 liter direct injection diesel engine and electric motor that powers the front wheels. It is equipped with a small lithium-ion battery. DaimlerChrysler says the car gets 72 mpg and has a range of 400 miles. Although the hybrid ESX3 will likely never be mass-produced, DaimlerChrysler did note that this car would only carry a price premium of $7500 over the cost of a comparable sedan. The vehicle's lower pricetag results in part from the use of a plastic body frame that's cheaper and easier to make than a steel or aluminum car.

Finally, GM has also shown a concept hybrid SUV. The Chevrolet Triax, unveiled at the 1999 Tokyo Auto Show, has an electric motor in the front of the vehicle; the rear third of the vehicle holds the internal combustion engine; and the middle third houses the vehicle's batteries.

Gasoline SULEVs

Definition

The California Air Resources Board defines a SULEV as a vehicle that achieves a 96% reduction in hydrocarbons, a 95% reduction in nitrogen oxides, and a 70% reduction in carbon monoxide, as compared against vehicles meeting the current basic standard. In addition, vehicles that meet the SULEV standard, have no evaporative emissions and meet the requirements for On Board Diagnostics, qualify for zero emission vehicle credits under the ZEV mandate.

Availability

CARB has designated two internal combustion engine cars for model year 2000 as SULEVs meeting the ZEV mandate: the Honda S2000 Accord and the Nissan Sentra CA. The S2000 Accord has a 2.3 liter, 4-cylinder engine. It achieves SULEV emissions reductions with advanced Ultra-Low Emission Vehicle technology and new catalytic converter technology. The car, which was due to become available in February, is priced at $23,200, only $100 more than the model it is replacing.

The smaller Nissan Sentra CA has a 1.8 liter engine and is also equipped with advanced environmental technologies that, in addition to reducing tailpipe emissions, allow the car to emit no gasoline vapors. According to Nissan, a Sentra CA that was driven for a 20-mile round trip commute would emit fewer harmful vapors than a car sitting in the driveway all day long. The Sentra CA does require low-sulfur fuel, available only in California, to achieve its emissions reductions. The Sentra CA is scheduled to go on sale in California in February.

Fuel Cell Vehicles

Fuel cell vehicles are still in the prototype stage; however, most of the major automakers are investing heavily in development of this new technology, and are predicting that fuel cell cars will be ready for commercial introduction within this decade. Fuel cell vehicles offer the possibility of zero emission operation with no recharging and with high performance.

Definition

A fuel cell produces electricity from the reaction of hydrogen and oxygen. Hydrogen is passed through the fuel cell, where it is separated into an electron and a hydrogen ion. There are different types of fuel cells under development, but essentially, what happens is that the ions combine with oxygen, creating water, while the electrons are directed to the electric motor. The only by-product of this process is water - there are no pollutants and no carbon dioxide emissions. This process is much more efficient than the internal combustion process - as much as 2 or 3 times more efficient.

A significant issue with fuel cell vehicles is how to supply the hydrogen. There are different methods of providing the hydrogen "fuel" to the fuel cell, and some of these have emissions associated with them. If the hydrogen is stored on board, the vehicle is truly zero emission. However, most automakers are considering a different method: deriving the hydrogen from another fuel, such as methanol or gasoline, that is stored on the vehicle. "Reformation" of methanol and gasoline would produce some air pollution, although significantly less than an internal combustion vehicle. Reformation also results in CO_2 emissions. Because the fuel cell is more efficient, CO_2 emissions are reduced by about half.

Availability

All of the major automakers are working on fuel cell vehicles, with target commercialization dates in the 2003 – 2005 timeframe.

DaimlerChrysler has made the most progress towards developing a commercially viable fuel cell vehicle. Earlier this year, the automaker unveiled the fourth generation of its fuel cell-powered Mercedes A-Class hatchback and has made a commitment to introduce the fuel cell A-Class by 2004. The A-Class is a subcompact that fits five people. The fuel cell, manufactured by Ballard Power Systems, is fed by an on-board methanol reformer, giving the car a 50% reduction in CO_2 emissions.

In 1997, Ford entered into a highly publicized alliance with what was then Daimler-Benz to develop fuel cell cars for commercialization by 2004. This year, Ford reiterated its goal of commercialization by 2004 when it unveiled a fuel cell concept car, the FC5, at the Frankfurt Auto Show. Ford says the 5-passenger FC5 "offers a realistic look" at what kind of fuel cell car will be ready for low-volume production by 2004. The FC5 also features a Ballard fuel cell stack and on-board methanol reformer.

GM and Toyota have also teamed up to develop a fuel cell car or truck for commercial introduction by 2003 or 2004. Honda has announced that it intends to make a fuel cell vehicle available by 2003.

Appendix

Fact Sheet

California Environmental Protection Agency
Air Resources Board

Zero-Emission Vehicles

Facts about cars and air pollution

In 1990, the California Air Resources Board (ARB) recognized that even the cleanest gasoline-powered vehicles wouldn't reduce pollution enough to satisfy the state's goals for healthful air. Meeting state and federal air standards in seriously polluted areas such as Los Angeles would require either restrictions on driving or a large-scale switch to cars and trucks that don't pollute.

Encouraged by advances in the development of battery-powered electric cars, the ARB acted to spur the development of zero emission vehicles (ZEVs)—cars and trucks without tailpipe or evaporative emissions. The Board adopted a requirement that in 2003 ten percent of the new vehicles produced for sale in California would have to be ZEVs.

Necessary for clean air

- Over 95% of all Californians live in areas which do not meet healthy air standards set by federal and state governments.
- Conventional gasoline-powered and diesel vehicles contribute over 60% of the smog-forming pollutants in California.
- Cars sold in California today are 98% cleaner than they were just 20 years ago, but as California's population and transportation needs grow, emissions from cars must be practically zero for California to meet its air quality goals. Replacing gasoline-powered vehicles with ZEVs is one of the best ways to do this.

Benefits beyond reducing smog

- ZEVs can reduce carbon dioxide emissions, the primary greenhouse gas.
- They reduce people's exposure to toxic air contaminants such as benzene and 1,3- butadiene.
- They benefit our society by providing high tech jobs in California.
- They also help diversify our energy needs and reduce our dependence on oil.

ZEVs are on the market today

Auto manufacturers are now producing EVs in a variety of styles and sizes including passenger cars, mini-vans, sport utility vehicles and pickup trucks. Check the table on the back for a list of the EVs available today.

What's a Zero-Emission Vehicle (ZEV)?

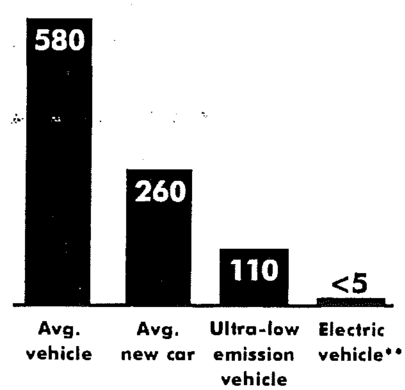
A zero-emission vehicle has:

- no tailpipe emissions,
- no evaporative emissions,
- no emissions from gasoline refining or sales, and
- no on-board emission control systems that can deteriorate over time.

Electric vehicles (EVs)—powered by batteries—are currently the only technology capable of meeting the ZEV requirements. However, in the near future other promising technologies such as fuel cells and hybrid electric vehicles may qualify as ZEVs.

Your Car's Smog Contribution*

(Pounds per 100,000 miles)



* Smog-forming gases—ROG + NOx (1997)
** Includes power plant emissions

With power plant pollution factored in, electric cars are over 90% cleaner than the least-polluting conventional gasoline-powered vehicles.

Are ZEVs really cleaner or do they just move pollution from the car to the power plant?

- Power plants in Southern California are very clean due to stringent air quality regulations; therefore, even taking power plant emissions into account, ZEVs are over 90% cleaner than the cleanest conventional gasoline-powered vehicles.
- Emissions from power plants are easier to control than emissions from millions of gasoline and diesel vehicles throughout the state.
- Future power plants will be even cleaner as they move towards using more renewable energy sources such as wind, solar and hydropower.

ZEVs (Electric Vehicles) Currently Available

Vehicle	Initial Market	Battery	Driving Range
GM EV1	Consumer/Fleet	Enhanced lead acid	50 - 70 miles
GM EV1	Consumer/Fleet	Nickel-metal hydride	80 - 120 miles
Chevrolet S-10	Fleet	Nickel-metal hydride	50 - 70 miles
Honda EV PLUS	Consumer/Fleet	Nickel-metal hydride	70 - 90 miles
Ford Ranger	Consumer/Fleet	Nickel-metal hydride	50 - 70 miles
Toyota RAV4	Fleet	Nickel-metal hydride	60 - 80 miles
Nissan Altra EV	Fleet	Lithium Ion	60 - 80 miles
Chrysler Epic	Fleet	Nickel-metal hydride	70 - 80 miles

For more information

Please contact the Air Resources Board's Public Information Office at (916) 322-2990, or (800) END-SMOG (363-7664) toll-free (USA only).

You may obtain this document in an alternative format by contacting ARB's ADA Coordinator at (916) 322-4505 (voice); (916) 324-9531 (TDD), Sacramento area only); or (800) 700-8326 (TDD, outside Sacramento).

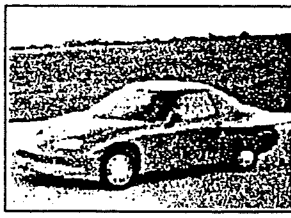
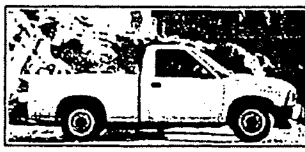
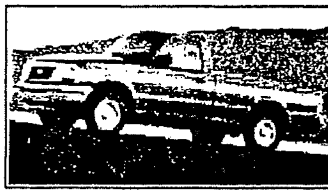
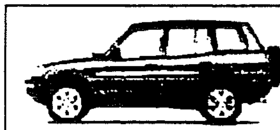
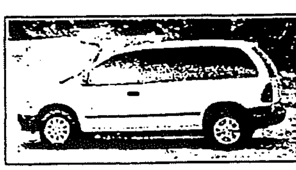
ZEVs Available in California

This page updated January 31, 2000.

ZEVs are a key element of California's plan for reducing air pollution caused by automobiles. ARB is committed to the successful introduction of ZEVs and is taking steps to ensure the market is ready.

Electric Vehicles Currently Available in California:

The Electric Vehicles available to the public are linked to the manufacturer's web site. Click on the links below to find a dealer near you.

Zero-Emission Vehicles		Battery Technology	Driving Range (miles)
Gen II GM EV1		Advanced Lead Acid	70-90
Gen II GM EV1		Nickel-metal Hydride	125-150
Chevrolet S-10		Nickel-metal Hydride	50 - 70
Honda EV PLUS (not available)		Nickel-metal Hydride	80 - 100
Ford Ranger		Nickel-metal Hydride	60 - 80
Toyota RAV4		Nickel-metal Hydride	80-100
Nissan Altra EV		Lithium Ion	80 -100
Chrysler EPIC		Nickel-metal Hydride	70 - 80

California Air Resources Board

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-- ZEV Fact Sheet --
Zero-Emission Vehicle Incentive

This page updated December 29, 1999.

ZEVs are a key element of California's plan for reducing air pollution caused by automobiles. ARB is committed to the successful introduction of ZEVs and is taking steps to ensure the market is ready.

Why are Incentives Necessary?

Incentives are commonly used by the government to promote the introduction of new technology that will benefit society. Because ZEVs are a new technology and are currently produced in very limited quantities, they are more expensive than conventional vehicles, similar to the first computers and VCRs. Once ZEVs are mass produced using mature production methods, it is expected that ZEVs will be comparably priced to conventional vehicles. However, to enhance marketability in the near term while costs are high, it is vital to provide monetary and non-monetary support in the form of incentives.

Currently Available EV Incentives:

There are a number of federal, state, local and private incentive programs currently available. Those incentives pointed to with a , apply to private consumers that purchase or lease an electric vehicle in California.

Federal	Utility
State/Local	Infrastructure

Federal Incentives

- Tax credit for 10% of the cost of an EV, up to $4,000. This incentive will be in place through 2004 but will be reduced by 25% in 2002, 50% in 2003 and 75% in 2004. For additional information, go to the Internal Revenue Service Electric Vehicle Credit web site.

- Elimination of the luxury tax for alternative-fuel vehicles. Contact the Internal Revenue Service for more information.

    - IRS form 8834, Qualified Electric Vehicle Credit. To claim a tax credit for the purchase of a qualified EVs and hybrid electric vehicles.

- IRS publication 535, Business Expenses covers the Clean Fuel Vehicle tax deductions.

Business tax deduction of $100,000 for electric recharging sites.

The Energy Policy Act of 1992 includes a ten year $50 million EV demonstration program and a fifteen year $40 million cooperative program between government and industry to research, develop and demonstrate EV infrastructure

California State and Local Incentives

- The California Energy Commission (CEC) and the U.S. Department of Energy have provided up to $5,000 (cap of $200,000) toward the lease or purchase of an EV in the following Clean Cities:
  - Bay Area, Orange, Riverside, Sacramento, San Bernardino, San Diego, Santa Barbara, Ventura and Yolo-Solano.
- The South Coast Air Quality Management District and San Diego Air Pollution Control District offer $5,000 toward the purchase or lease of an EV.
- The Los Angeles Airport (LAX) offers free parking and charging for EVs in Lot 1 in the Central Terminal Area and Lot C.
- The City of Sacramento offers free parking to EVs with an EV parking pass in downtown parking lots.
- SB 1782 (Thompson) exempts from the vehicle license fee, the incremental cost associated with purchasing or leasing an alternative fuel or electric vehicle that meets ultra-low emission standards.
- AB 71 allows single occupant electric vehicles use the high occupancy vehicle or carpool lanes beginning July 1, 2000.
  - Click here to view the Electric Vehicle Association of the Americas 1999 EV Related State Legislative Actions or State Laws and Regulations impacting electric vehicles.

The (CEC) will provide funding assistance to the EV Loan Program for chargers and installation of infrastructure.

Utility Incentives

- Edison International offers an employee incentive program that allows $3,600 towards the lease of purchase of a qualifying EV. This program is funded by the corporation's shareholders and combines a cash buy-down with special packages from four major auto manufacturers to make daily use of an EV easier for employees.

- Los Angeles Department of Water and Power provides discounts of $0.025 per kilowatt hour (kWh) for electricity used to recharge EVs.

- San Diego Gas and Electric offers a discount rate of $0.036/kWh for electricity used to recharge EVs during off-peak time periods. They have a total of $50,000 in seed money to help local businesses and governments install charging stations in its service area.

- Sacramento Municipal Utility District (SMUD) offers a discount rate of $0.04187/kWh for electricity used to recharge EVs during off-peak time periods.

- Pacific Gas and Electric offers a discount rate of between $0.044/kWh to $0.051/kWh for electricity used to recharge EVs during off-peak time periods.

- Southern California Edison offers a discount rate of $0.04/kWh for electricity used to recharge EVs during off-peak time periods.

Infrastructure Incentives

- CEC, local air quality agencies and some auto manufacturers provide funding assistance for EV infrastructure. For additional information contact CEC, your local air district or auto manufacturers.

- The SCAQMD provides funding assistance for EV infrastructure through the "Quick Charge" program

- The Bay Area Air Quality Management District provided funding assistance for EV infrastructure through its "Charge" program.

  The CEC provides funding assistance to the EV Loan Program for chargers and installation of infrastructure.

For further information on ZEV incentives:

For more information, you may wish to contact your local air pollution control district, Dave Ashuckian at the California Energy Commission or Lisa Kasper at the Air Resources Board.

Fuel Cell Electric Vehicles

Fuel cells have captured worldwide attention as a clean power source for electric vehicles (EVs). EVs powered by fuel cells are being developed by many auto manufacturers, and have generated interest and enthusiasm among industry, environmentalists and consumers.

What are the benefits?

A fuel cell EV, powered by an electric motor, promises the air quality benefits of a battery-powered EV, combined with the driving range and convenience of a conventional gasoline engine. Compared to conventional vehicles, fuel cell EVs can offer:

- zero or near-zero smog-forming emissions,
- reduced water pollution from oil leaks,
- lower greenhouse gas emissions (CO_2),
- higher fuel economy,
- greater engine efficiency and
- much quieter and smoother operation.

If alternative fuels are used as a source for hydrogen, fuel cell EVs will also encourage greater energy diversity.

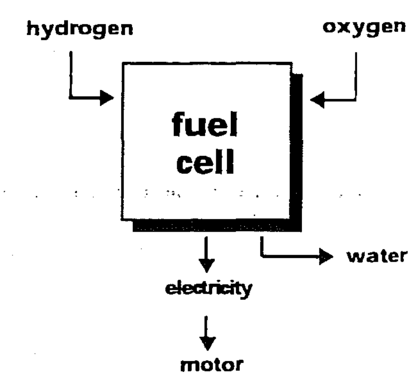
A fuel cell using pure hydrogen produces no pollution. However, the production of hydrogen gas for use in fuel cells is expected to result in extremely low air pollution emissions.

What is a fuel cell?

In principle, a fuel cell operates like a battery. A fuel cell converts chemical energy directly into electricity by combining oxygen from the air with hydrogen gas. However, unlike a battery, a fuel cell does not run down or require recharging. It will produce electricity as long as fuel, in the form of hydrogen, is supplied.

Fuel cells have been a reliable power source for many years. Applications include electrical power supply for space flights as well as conventional electric power generation in buildings and power plants.

A Fuel Cell at Work



Fuel cells convert hydrogen and oxygen (from the air) into electricity and water.

How Does A Fuel Cell Work?

An individual fuel cell consists of two electrodes, one positively charged (cathode) and one negatively charged (anode), with a substance that conducts electricity (electrolyte) sandwiched between them. Oxygen from the air passes over the cathode and hydrogen over the anode, generating electricity and water.

The hydrogen fuel for a fuel cell EV can be supplied in several ways. Some vehicles carry a tank of pure hydrogen. Others could be equipped with a "fuel reformer" that converts hydrocarbon fuels—such as methanol, natural gas, or gasoline—into a hydrogen-rich gas.

Individual fuel cells must be combined into groups called fuel cell stacks in order to achieve the necessary power required for motor vehicle applications.

What is the current status of fuel cell electric vehicles?

Impressive advances in fuel cell technology have been made over the last several years. Auto manufacturers such as DaimlerChrysler, Ford, Toyota and General Motors have announced plans to have fuel cell EVs commercially available by 2004. Prototype passenger vehicles are now being tested. Transit buses powered by fuel cells are currently carrying passengers in public demonstration programs in several North American cities.

What is ARB doing to support fuel cell electric vehicles?

Fuel cells are a very promising technology for use in both light-duty and heavy-duty vehicles. ARB is working closely with public and private partners on research and development, vehicle demonstration programs, and the infrastructure and safety requirements needed to support these vehicles.

In 1996, ARB established the Fuel Cell Technical Advisory Panel (Panel). The Panel independently assessed developing fuel cell technology and the prospects for fuel cell EVs within the next five to ten years. It concluded that fuel cell stacks now meet all of the key requirements for automotive propulsion. Technical challenges that remain include the integration of fuel cell stacks, fuel processors and auxiliary components into commercial EVs that meet consumer demands for performance and cost. All major auto manufacturers are making significant progress toward integrating these components and reducing their cost.

California Fuel Cell Partnership

ARB is a founding member of the California Fuel Cell Partnership, a collaboration of auto manufacturers (DaimlerChrysler and Ford), fuel providers (Arco, Shell and Texaco), a fuel cell developer (Ballard), and government agencies (ARB and the California Energy Commission). The Partnership will bring fuel cell electric vehicles to California beginning in 2000, and seeks to demonstrate the potential of this new technology as a safe, practical, clean and efficient alternative to conventional vehicles.

For More Information

For more information, please contact the ARB toll-free at (800) END-SMOG/(800) 363-7664 (California only) or (800) 242-4450. You will also find information on fuel cells at ARB's web site— http://www.arb.ca.gov or at the California Fuel Cell Partnership web site at http://www.drivingthefuture.org.

You may obtain this document in an alternative format by contacting the ARB's ADA Coordinator at (916) 322-4505 (voice), (916) 324-9531 (TDD, Sacramento area), or (800) 700-8326 (TDD, outside Sacramento).

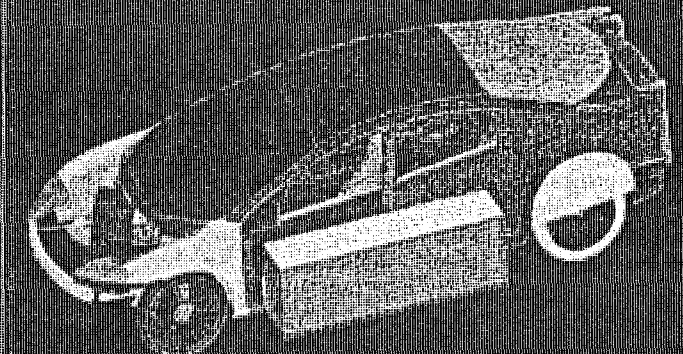
Newsweek 11/23/98

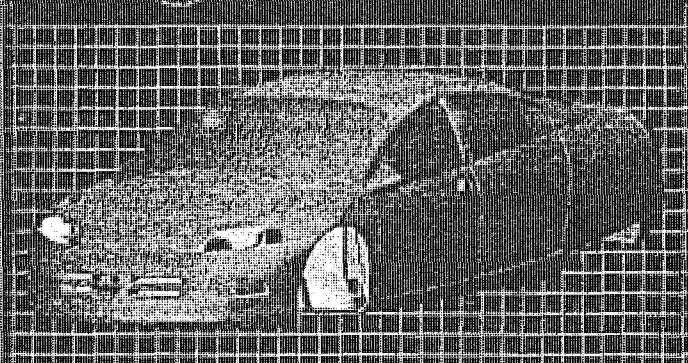
Shock of the New: Automakers don't know how it will work or how to sell it, but get ready. The car of the future is coming—sooner than you think. BY DANIEL MCGINN AND ADAM ROGERS

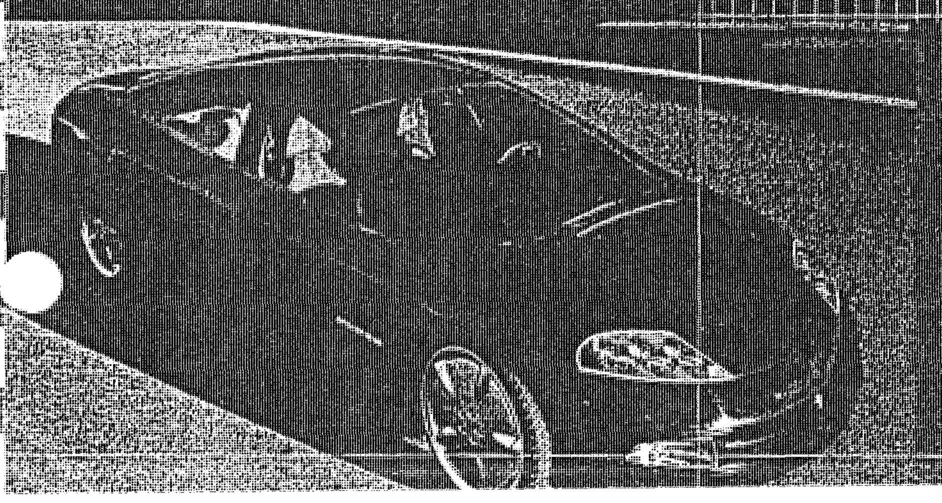
Operation:

BUILDING 371 AT ARGONNE NATIONAL Laboratory outside Chicago looks like a dingy old warehouse—but to scientists, this is hallowed ground. In the 1960s the site held one of the world's largest atom smashers, and physicists working here helped decipher the subatomic structure of matter. Today the engineers who work in 371 have a very different mission: helping America's automobile companies build a supercar. On a typical day researchers tinker with a Toyota Prius, a high-tech vehicle already on sale in Japan, removing components and crunching data. Their goal: to show Detroit how to build something superior. Says facility manager Bob Larsen: "We're plowing new ground all over the place."

As they are in Munich ... and Tokyo ... and Detroit. Auto manufacturers round the world are accelerating toward fantastic goals: creating vehi-

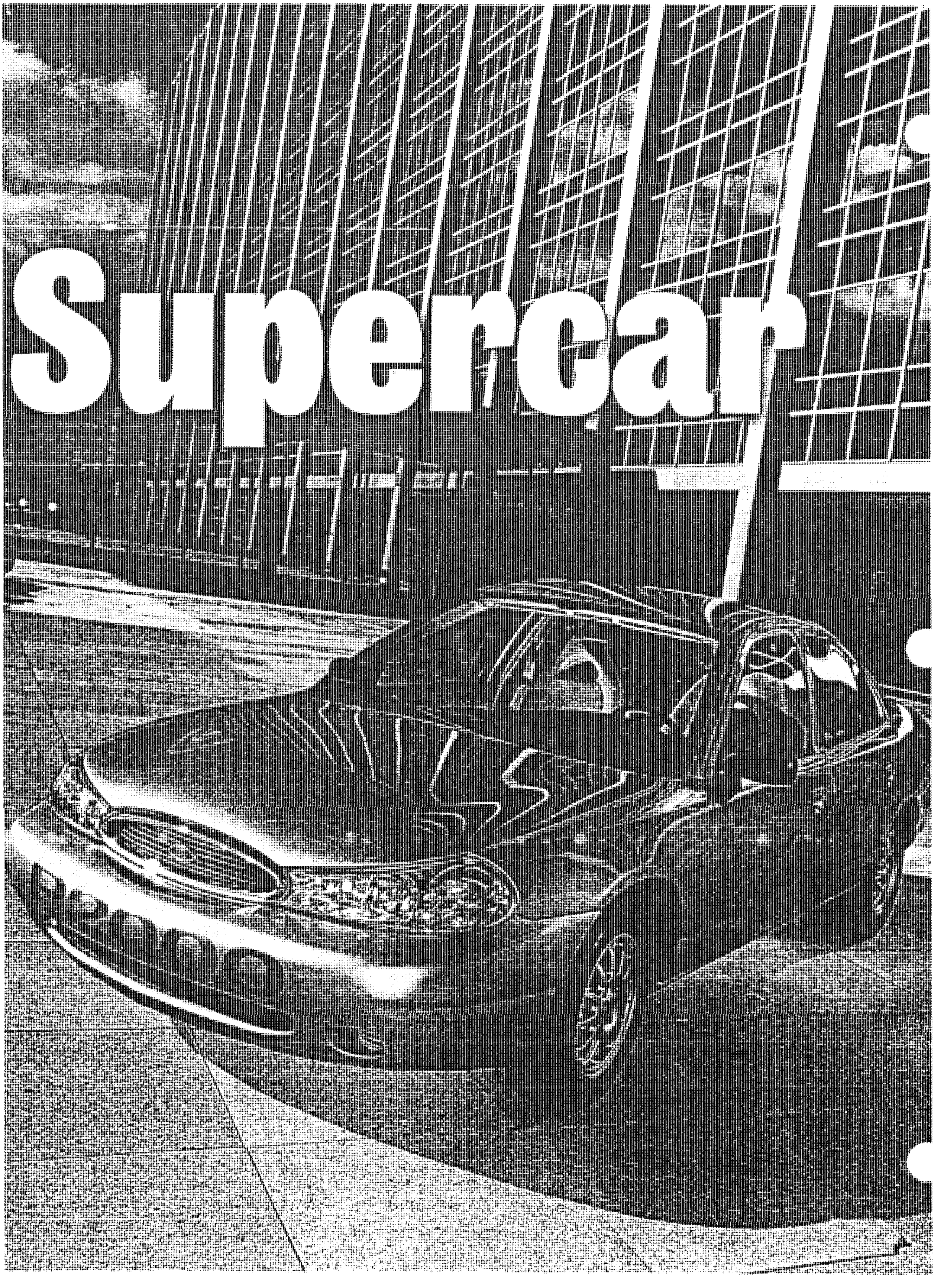






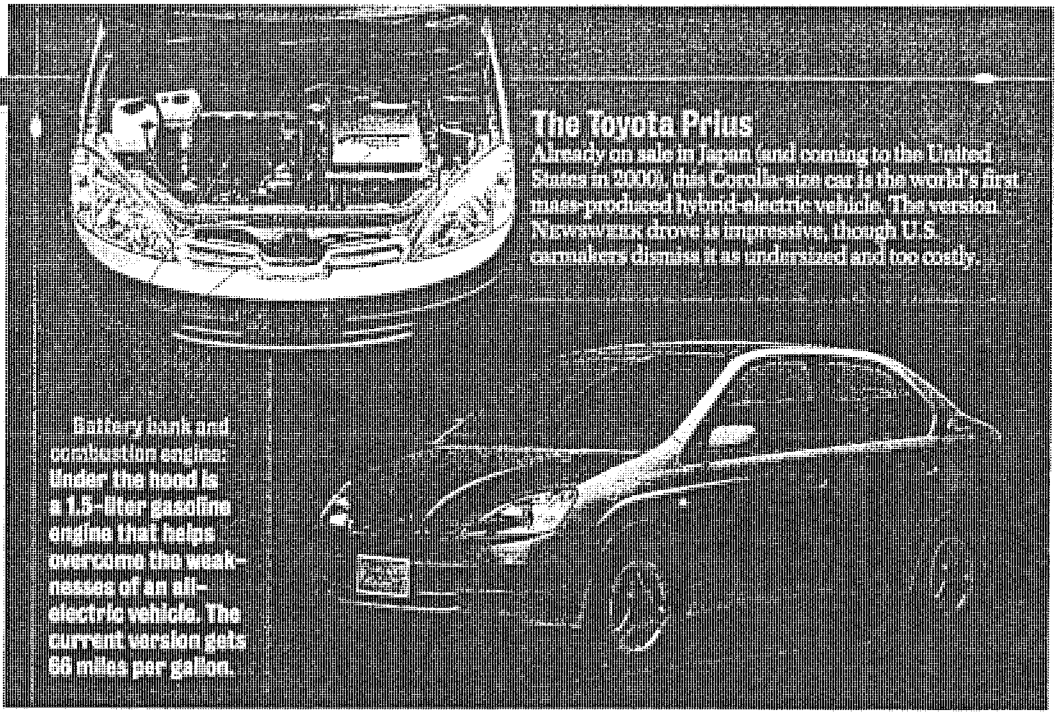
The Chrysler ESX 2
(Left, above) Inside its aerodynamic shell (which reduces drag) is a hybrid-electric power train, delivering 70 mpg. The computer-controlled manual transmission takes getting used to, but for a one-of-a-kind prototype, the ride's not half bad.

The Ford P2000
(Right) Its beauty isn't under the hood—it's in the lightweight aluminum body, which helps this vehicle achieve 63 mpg without a space-age engine. Drives like a normal car, you say? That's the point.


Supercar

ars that cruise 80 miles on a gallon of fuel, while emitting just a whiff of the harmful gases that escape today's tailpipes. To get there, they're placing varied bets on vehicles that run on diesel and propane, electricity and hydrogen. But lately a consensus has formed around two technologies that may finally lead a slow waltz away from the gasoline engine. In the next decade, experts say, we'll see the emergence of hybrid-electric vehicles, like Toyota's Prius, which run on a combination of engines and batteries. Then, just as the vacuum tube gave way to the transistor, the hybrids will be killed off by the auto industry's holy grail: the fuel cell, which could someday bring pollution-free driving. General Motors chairman Jack Smith used to think fuel-cell vehicles wouldn't be ready until 2020; now GM plans to have prototypes by 2005. Says Smith: "The work going on ... is unbelievable."

That kind of rosy futurism is getting pretty common in the Motor City. Auto executives—most notably Ford's incoming chairman, William Clay Ford Jr. (following story)—sound downright green when they talk about new vehicles. With gasoline at $1 per gallon, most Americans couldn't care less—and the internal-combustion engine is far from an endangered species. That may be good: no one wants a world where cars go obsolete as fast as computers. So there may be no eureka moment in this technology hunt. Instead, we may see semi-supercars first, as vehicles become incrementally cleaner and more efficient, as they've done for decades. Either way, get ready for a future driving something



The Toyota Prius
Already on sale in Japan (and coming to the United States in 2000), this Corolla-size car is the world's first mass-produced hybrid-electric vehicle. The version NEWSWEEK drove is impressive, though U.S. carmakers dismiss it as undersized and too costly.

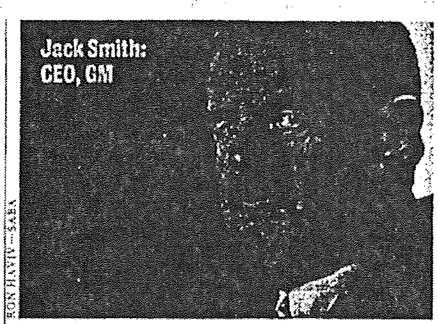
Battery bank and combustion engine: Under the hood is a 1.5-liter gasoline engine that helps overcome the weaknesses of an all-electric vehicle. The current version gets 66 miles per gallon.

I N T E R V I E W

The View From the Big Three

The CEOs weigh in on the future of cars and car buying

THESE ARE BUSY DAYS IN the Motor City. Since last summer's crippling strike, General Motors chief executive Jack Smith has unveiled two major reorganizations, the latest big steps in GM's continuing turnaround. At Ford, CEO-to-be Jacques Nasser is building his new team of execs who'll run the industry's second largest player. Then there's Robert Eaton of Chrysler—excuse us, DaimlerChrysler—who this week will ring the bell opening New York Stock Exchange trading in DCX, his transatlantic company's new ticker symbol. Amid these changes the three CEOs met separately with NEWSWEEK editors this month. Edited excerpts:



Jack Smith: CEO, GM

RON HAVIV—SABA

Where are you on the race for a cleaner car?
SMITH: The technology is moving fast. What isn't moving as fast, which is always the difficult part, is, how do you get the cost down so people can afford to buy it. It's a huge issue. It will come, but it comes much slower than the technology.

Can't you charge more for a high-tech vehicle?
EATON: People are too practical. There's a certain element who will fall in love with new technology, but technology won't survive unless it's cost-effective.

When will we see a supercar on the road?
NASSER: [During my career] I think you'll see fuel-cell vehicles becoming a viable alternative for many people ... I [also] think we'll see a refinement of the internal-combustion engine. There's still a lot of potential left in that, particularly as electronics and technology improve and lightweight materials become more affordable.

Your companies lead in the sales of sport utility vehicles, which aren't as clean and use more gas than cars. Aren't they a problem?
NASSER: When you look at the trucks we're selling today, these vehicles are 90 percent cleaner than the small vehicles of the '70s and '80s. Their fuel economy is better than the so-called compact vehicles of the '60s and '70s. I think what we'll see is a continuation, and probably an acceleration in that direction.
SMITH: [The problem is] gasoline is too cheap in this country. It's selling for 85 cents a gallon in Atlanta ... In the rest of the world it costs close to $5 a gallon. When you ask "Do we need regulations?" [the answer is] no. We just need higher gas prices. That will change what people do.
EATON: You're not going to believe this but we're as concerned about the environment as anyone else. [We] started working on President Clinton for a 50-cent gas tax when he was still in Little Rock ... We want to produce what the mar-

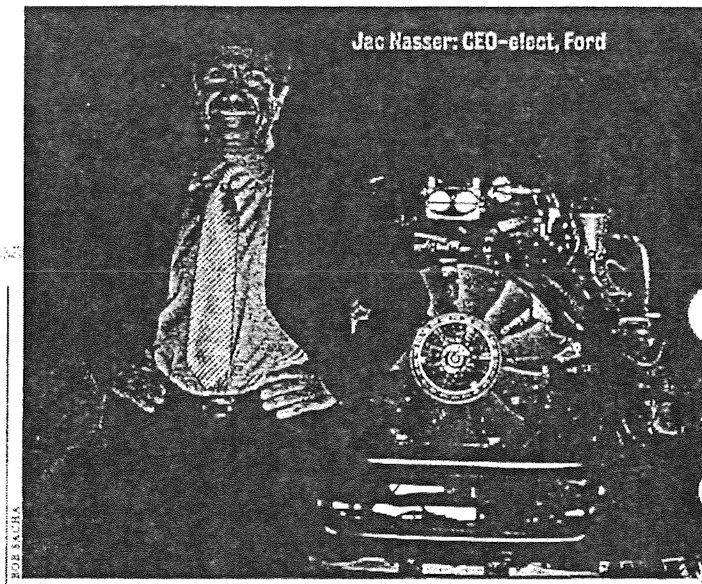
very unlike your father's Oldsmobile.

To create it, American carmakers are getting some high-powered help. Through a Clinton administration program called the Partnership for a New Generation of Vehicles (PNGV), government scientists are riding shotgun in the search for a fuel-efficient car. While the government helps with basic research (like developing better batteries), the carmakers work in secret to package those gizmos into workable vehicles. Critics say the project is just the latest techno-hype. "We view it as a scam" designed to fend off regulations, says the Sierra Club's Daniel Becker. Says Ralph Nader: "Until [the products] are on the showroom floor, it's nothing more than razzle-dazzle, R&D flimflam."

He's partially right: at times this race resembles one big science fair, a show-and-tell in which carmakers have no obligation to actually sell their creations. That's because supercars face serious cost hurdles before they approach profitability. But make no mistake: the technical achievements are real. NEWSWEEK has driven prototypes that get up to 70 mpg (more than double an average car's efficiency), and all three U.S. car companies will unveil 80-mpg prototypes in early 2000 (yes, that includes DaimlerChrysler: despite speculation that its new German roots will get it booted from PNGV, cochairman Robert Eaton tells NEWSWEEK the Clinton administration wants DaimlerChrysler to stay put). President Clinton calls the companies' work "as ambitious and complex as the Apollo mission." If only it were that easy. "In the space program, it was, 'Can we make this work once, give or take a few billion dollars?' " says Ford research vice president Bill Powers, who worked on Apollo rockets and the space shuttle. "In the auto industry it's, 'Can I make over a million of these, at a reasonable cost, that will be used by untrained drivers and last 10 years and 150,000 miles?' "

There's an additional question: will you buy one? That's a hurdle the folks at GM's Advanced Technology Vehicle Center know well. Their building is filled with plaques and team photos, hoopla left over from the creation of the EV1, the electric vehicle GM put on sale in 1996. The world once believed a battery-powered car would end our petroleum habit, and the EV1 is a technical triumph—but consumers have ignored it. Even environmentally conscious drivers are scared off by its limited range (it goes just 70 miles between charges). The electric vehicle, most experts now agree, is a niche product.

To transcend that niche, researchers have focused on the hybrid-electric vehicle. To understand it, imagine a car powered by two treadmills. Jogging on one is marathon champion Joan Benoit. Like the small diesel engine that helps power a hybrid, Benoit is great for a long, slow-and-steady trip, but she lacks the speed and power to pass on a highway or dash up a steep hill. The athlete on the second treadmill, sprinter Michael Johnson, has incredible power but no stamina; like the EV1, he's not built for long distances and needs frequent breaks to recharge. Hybrid vehicles at-


Jac Nasser: CEO-elect, Ford

BOB SACHA

ket wants. If it's in society's best interest, which I think it is, to consume less resources, I want the customer to want that. Don't tell me to sell him [a product] he doesn't want.

What would you think of a Gore administration?

NASSER: Ford's a company that deals all over the world with all shades of politics, so I'm very neutral on individual politicians.

EATON: My job is to deal with whomever is in there in the very best way I can.

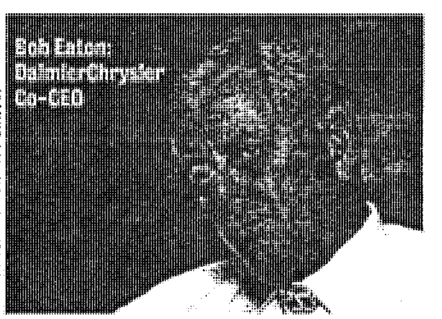
SMITH: Well, I must say I think I might prefer an alternative to that. [But] we've worked well with this administration. They're willing to listen to the problems of industry.

Jack, what makes this year's reorganization at GM different from all of the previous ones?

SMITH: GM didn't change a lot for a hell of a long time when we needed to change. The first change we made in 1984 didn't work right, then in 1992 we did it differently ... All of the effort that's taken place since 1992 is to run common in everything we do, and get away from [our] roots of [divisions] being very independent ... It takes a few years to get it all done.

Jac, some Ford employees seem afraid of you. Should they be?

NASSER: Are you afraid of me? No? That solves that ... I do have a strong desire to strengthen this company. The alternative is mediocrity ... What would you choose?


Bob Eaton: DaimlerChrysler Co-CEO

BILL PUGLIANO—GAMMA-LIAISON

Bob, you're portraying the Daimler-Chrysler deal as a "merger," but it looks like a takeover of Chrysler by Daimler.

EATON: There are [several] factors that caused a lot of people to make that conclusion. One of them is that the company is registered in Germany. Another is that I'm going to leave in three years ... I honestly quit bringing that up or arguing with anybody on it. I just say let them see what happens, and then that will all go away.

How is the dealer business changing?

EATON: Sixty-seven percent of customers don't like the retail experience. There's been a tremendous amount of experimenting going on to provide better customer satisfaction. There are the megastores ... the Internet ... We're going to go with whichever way is successful ... Bottom line: if the current dealers don't change, they'll go out of business ... But they are changing.

How is the Internet affecting car buying?

SMITH: It's already having some impact—not so much in buying the vehicle, but in knowledge of what's available ... We're seeing maybe 30 percent of customers coming into a dealership today having checked out various models on the Internet ... It gives us a challenge, because we have customers with more knowledge than the salesperson.

Ladies, Gentlemen: Start Your Engines

They can't tell you exactly *when* they'll hit showrooms, but automakers are talking excitedly about hybrid-electric and fuel-cell-powered cars that may have what it takes to eventually displace the gasoline engine. What's under the hood and how it works:

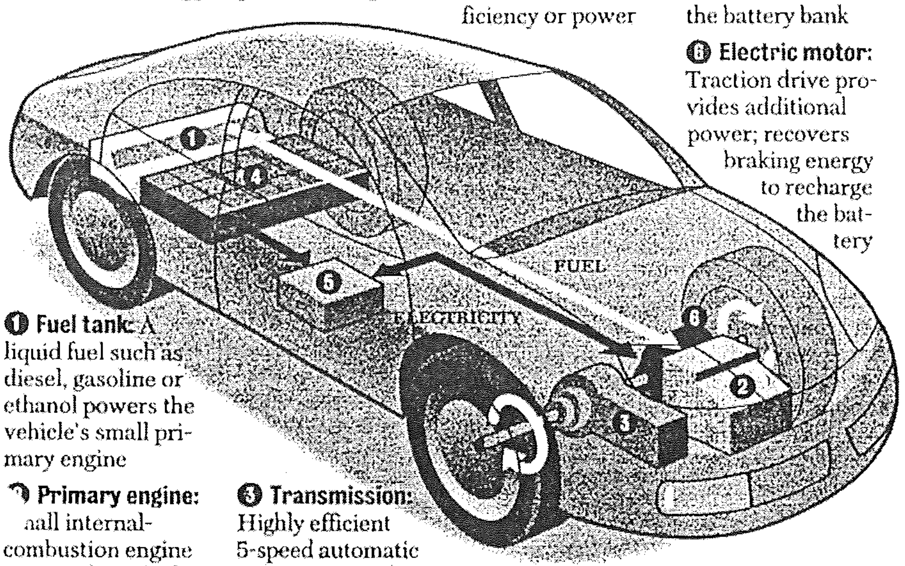
Hybrid car

They aren't as clean as electric vehicles, but their engines work with batteries to overcome EVs' biggest problem: range.

4 Battery bank: High-density batteries send power to the electric motor for added efficiency or power

5 Controller: Device that regulates the flow of power between the electric motor and the battery bank

6 Electric motor: Traction drive provides additional power; recovers braking energy to recharge the battery



1 Fuel tank: A liquid fuel such as diesel, gasoline or ethanol powers the vehicle's small primary engine

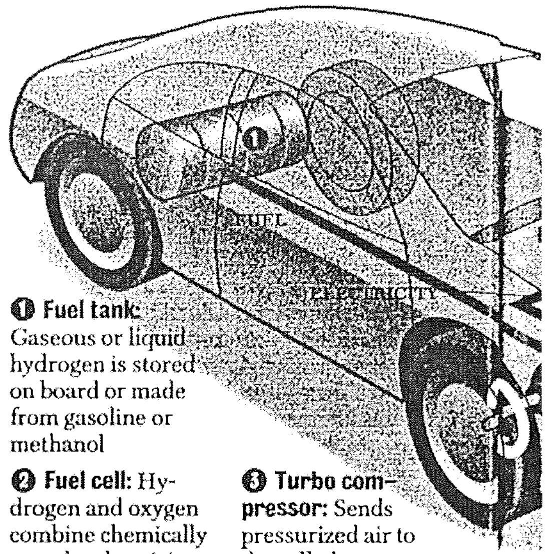
2 Primary engine: Small internal-combustion engine powers the vehicle efficiently and with low emissions

3 Transmission: Highly efficient 5-speed automatic transmission adjusts engine power to driving needs

SOURCES: DAIMLERCHRYSLER, FORD, USCAR
GRAPHIC BY STANFORD KAY—NEWSWEEK

Fuel-cell car

Electricity, produced without pollution, powers these vehicles. But cost and storage of hydrogen gas are challenges.



1 Fuel tank: Gaseous or liquid hydrogen is stored on board or made from gasoline or methanol

2 Fuel cell: Hydrogen and oxygen combine chemically to make electricity; water is the only byproduct (top)

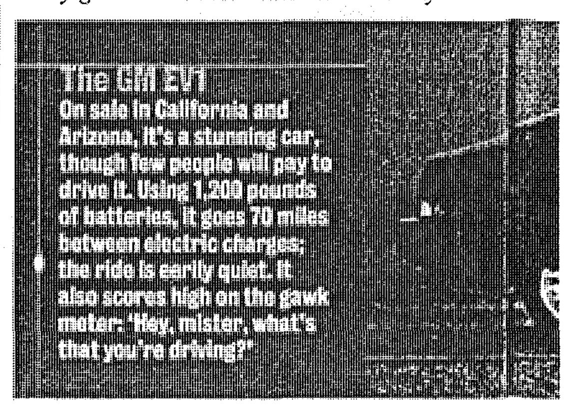
3 Turbo compressor: Sends pressurized air to the cell; the compressor is powered by exhaust steam

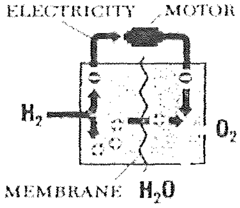
tempt to overcome each runner's limitations by combining them. Like Benoit, the steady diesel provides most of the power for cruising; the electrical system gives boosts for sprinting through jackrabbit starts, passing and other lead-footed or short-distance driving.

It sounds great in theory, but making it work is a challenge. At Chrysler, that task falls to Bob Lawrie, a goateed engineer who once worked in the pits with Lamborghini's racing team, and colleague David Bernier. It's a typical afternoon in DaimlerChrysler's test garage and they're working the kinks out of the software that coordinates the hybrid power train in a souped-up Dodge Neon. Suddenly smoke wafts from under the hood: a glitch has caused a wire to overheat. They're unfazed by the bug, but spend hours tediously rechecking code. Says Bernier: "The spotlight is on us to make it all work right."

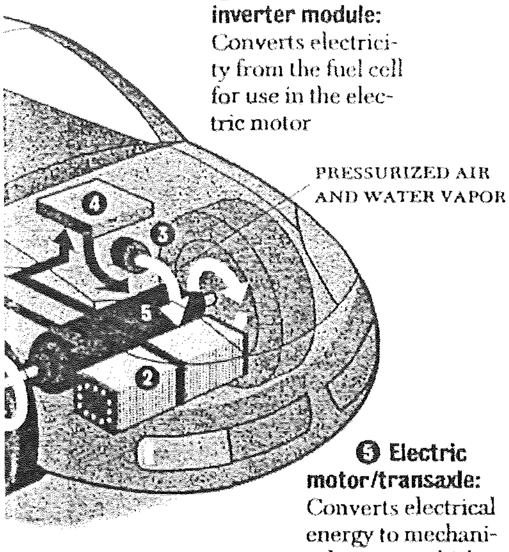
To environmentalists, hybrids are a mixed blessing. Since most use diesel engines, they're not a zero-emission solution. Today's diesels improve on their noisy, smelly predecessors. They emit less carbon dioxide (a greenhouse gas) than gasoline engines, but more oxides of nitrogen (called NOX) and particulates—bits of soot—which pollute the air. While engineers work on gadgets to control that—turbochargers, direct injection, new kinds of catalytic converters—Sandia National Laboratory researcher Bob Carling may have a different solution. A decade ago he helped design nuclear-pumped X-ray lasers for Reagan's Strategic Defense Initiative, but today, like a cardiac surgeon who uses tiny cameras to see inside a heart, Carling uses lasers and video screens to see exactly what's happening when fuel and air explode inside an engine. "In a diesel engine you can actually see each flame," Carling says. "In the big ones, you get this eight-plumed fireball." His goal: to find ways to make those explosions result in more power and fewer byproducts. Green advocates are still skeptical. "You can indeed make a diesel much quieter and cleaner," says Amory Lovins, director of research at the Rocky Mountain Institute. "But fuel cells will beat them, hands down."

Ah, the fuel cell, that magical-sounding device the whole industry is betting on. Send hydrogen through a sandwich of platinum catalysts and polymer electrolytes and out comes electricity to power a car. OK, it's slightly more complicated—which is why you're not driving one yet. "For years [carmakers] said, 'This whole thing is pie-in-the-sky'," says Los Alamos National Laboratory fuel-cell researcher Shimshon Gottesfeld. But now they're rushing to embrace it. They don't lack for work. Even if fuel cells were affordable (they're not) or the right size to fit in a car (not yet), the trick would still be how to pump gaseous hydrogen into a gas tank. After much research, the car companies now have a different plan. They're plotting to outfit cars with mini-refineries, which will convert gasoline or methanol into hydrogen, eliminating the need to bulldoze every gas station in America to install hy-





Fuel cell: Splits hydrogen into protons and electrons. The electrons (electricity) head for the motor and the protons pass through a membrane to merge with electrons and ambient oxygen, forming water.



Other fuel sources

While hybrids and fuel cells look most promising, carmakers are exploring a host of other technologies. A sampling:

Diesel
No longer putt-putt engines—new versions are cleaner and quieter.
■ PRO: Improved fuel economy over gasoline at a competitive price
■ CON: Higher emissions than gas contribute to smog and earn it the rep as a "dirty" fuel

Compressed natural gas
Used in taxis in New York and other fleets.
■ PRO: Lower emissions, plentiful U.S. supply, cuts engine wear
■ CON: Refueling stations are expensive, tanks limit trunk size and Americans prefer liquid fuels

Ethanol/methanol
Ford and Chrysler already sell vehicles that run on ethanol/methanol as well as gasoline.
■ PRO: Renewable fuels, and they work in existing engines with minor modifications
■ CON: Toxic, corrosive to engines and not as efficient as gasoline

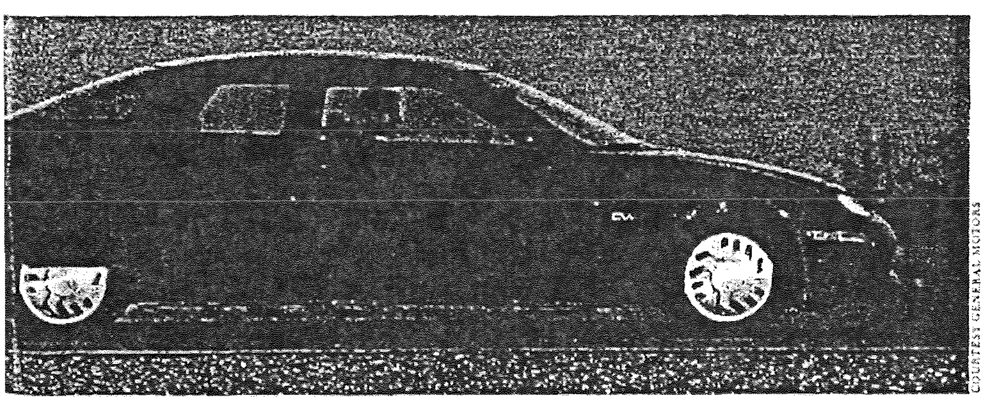
Electric
Most carmakers sell one to meet state mandates.
■ PRO: No direct emissions, quiet ride and the country is wired for electric
■ CON: Batteries are expensive and heavy, with short range and long recharging times

drogen tanks. But that strategy makes a complex process even tougher. "We have one running, but it looks like a rolling chemistry lab—the equipment fills up the entire back of the vehicle," says GM's Smith. "It's not exactly practical."

But rest easy: fantastic under-the-hood contraptions aren't the only way to wean us away from gasoline. In fact, supercar research has already shown how to boost fuel efficiency by putting cars through a Weight Watchers regimen, using space-age (but expensive) metals like titanium, magnesium and aluminun and smoothing down nonaerodynamic angles. Just last week GM signed a big contract that will increase its use of weight-saving aluminum in all models. Ford has the most tangible example of how this can work: its P2000 prototype is 40 percent lighter than a Taurus, which helps it achieve 63 miles per gallon without a space-age power train. Ford is reportedly developing a showroom-bound all-aluminum sport utility, too.

To package all these technologies into a vehicle, engineers juggle materials and power trains, trading off cost, weight and efficiency. That's the drill at Ford's Macro Team meeting, where two dozen engineers hash out their supercar prototype. They've already decided to build a mostly aluminum hybrid sedan, but they're still haggling hard. Curve the windshield glass a bit more to cut drag? Use a titanium exhaust to save weight? At every juncture, program director Vince Fazio asks variations of the same question: will this impede our ability to build real cars in a real plant, in big quantities? Their prototype still hasn't met supercar goals: it's 108 pounds too plump, four mpg below target, and so expensive they won't discuss costs. But they have 13 months to get it in shape.

Will they—or their competitors—send something like it to showrooms? Too soon to tell. Carmakers sold roughly 12,000 alternative-fuel vehicles in 1997 (mostly fleet vehicles running on compressed natural gas); selling more advanced hybrid electrics will depend on their ability to lower costs. Chrysler figures its ESX2 prototype would cost $35,000 to build; that has to drop to $20,000 to sell it. They also must generate consumer interest, which right now is pitifully low. The latter problem is mainly a function of gas prices, and that's why Europe is likely to see these futuristic wheels before us. The effort here could get a boost from Uncle Sam through a proposed tax credit to buyers of 80-mpg vehicles. But to make a hybrid vehicle profitable, Toyota and other carmakers say, they'd need to sell 200,000 a year. They'll all have the technology before 2005, but U.S. carmakers won't sell products philanthropically, as they say Toyota does with its Prius, which costs far more than its $16,000 sticker price. "My shareholders wouldn't like it if I was selling a significant number of vehicles at half their cost," says DaimlerChrysler cochairman Eaton. Fuel-cell cars require fuzzier crystal-ball gazing; although technology leader Daimler sees them coming in the next decade, most experts say they're at least 15 years away, primarily because of the infrastructure problems of how to get hydrogen to your gas tank.



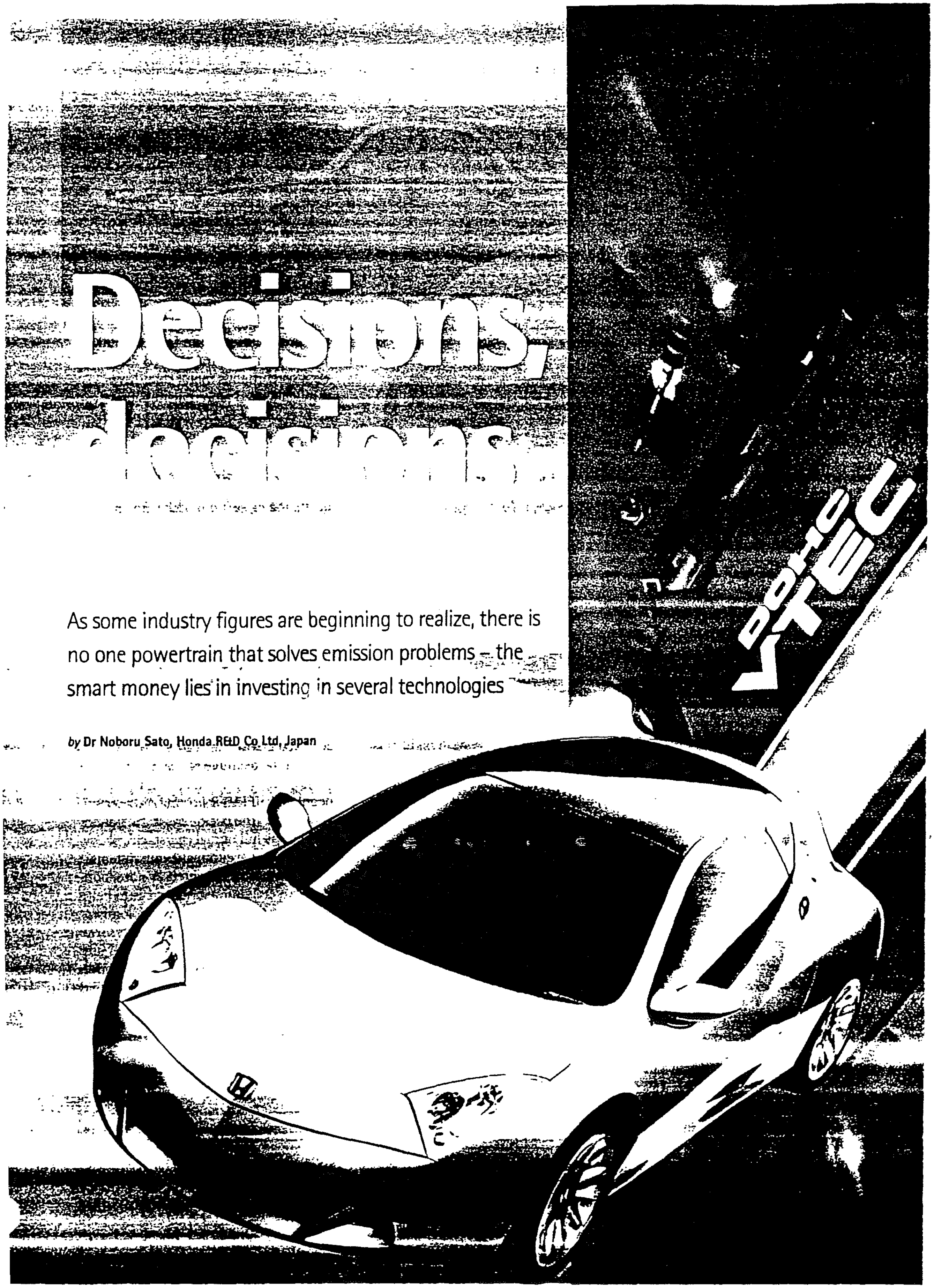
COURTESY GENERAL MOTORS

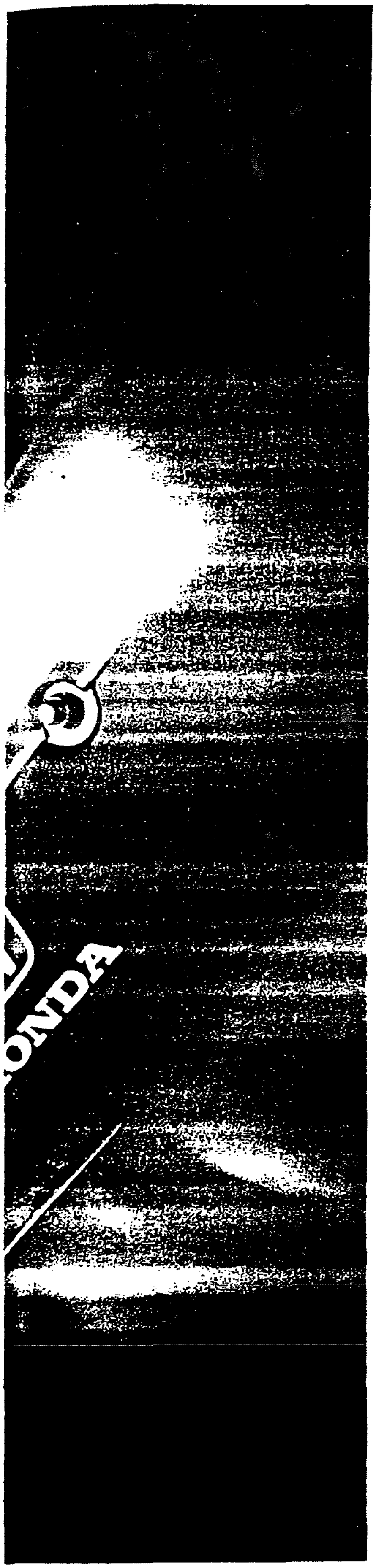
So these researchers may end up like van Gogh—important *eventually*, but receiving little acclaim in their lifetimes. That doesn't discourage GM's Ron York, who's forgone early retirement to stick with the project. "We have a chance to do something that could change the industry and change the world—God doesn't give you that many chances to do something like this," he says. DaimlerChrysler researcher Bernier looks forward to letting his two sons see his company's prototype at the 2000 Detroit Auto Show. "It's nice when you can show your family what you've dedicated two years of your life to," he says. We may never get to drive what he's working on, but those children, ages 4 and 2, probably will. ■

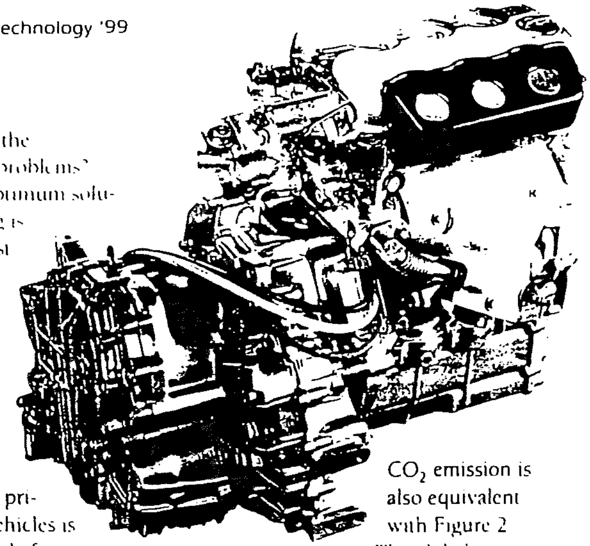
Decisions, decisions

As some industry figures are beginning to realize, there is no one powertrain that solves emission problems – the smart money lies in investing in several technologies

by Dr Noboru Sato, Honda R&D Co Ltd, Japan







How best to reduce the world's pollution problems? There is no one optimum solution, but one thing is for sure the automobile must clean up its act. Of course, us engineers are only too aware of this fact, but with the number of 'green' options at our disposal, choosing the right path is not as simple as those outside the industry believe

The relationship between primary energies and various vehicles is shown in Figure 1. Automobile factors like an increase in automobiles or traffic jams will cause an increase in fossil fuel consumption. Eventually, emissions of HC, NOx and CO_2 will be increased in accordance with these factors. Accordingly, the automotive industry should develop the future energies and advanced vehicles to contribute to a clean world towards the 21st century

Figure 2 shows the consumption of primary energies in 1997. The order of CO_2 emission is also equivalent with Figure 2.

The global production of automobiles reached 51.93 million vehicles in 1998. The number of units manufactured in major countries are shown in Figure 3, which indicates that production in the USA and Japan accounts for nearly half of overall production. Figure 4 indicates a prediction that the number of automobiles will abruptly increase in the world. We can see a slight increase in the developed countries, and on the contrary, a dramatic increase in

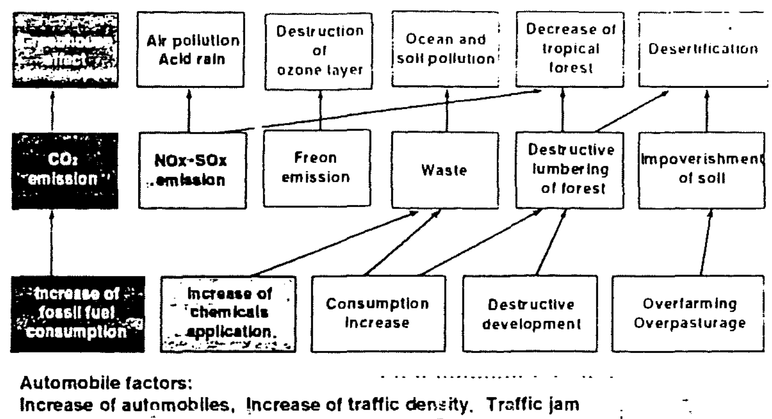


Figure 1: Relationship between earth environmental issues and automobiles

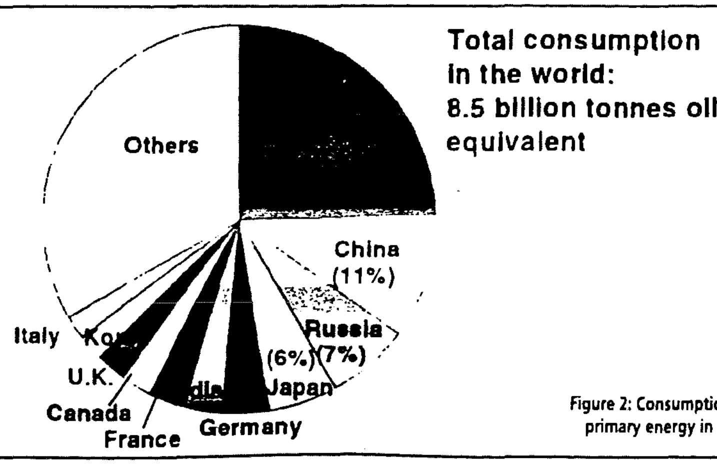


Figure 2: Consumption of primary energy in 1997

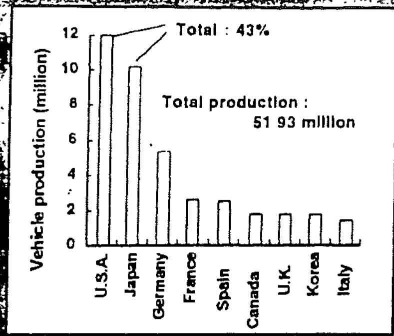


Figure 3: Annual automobile production

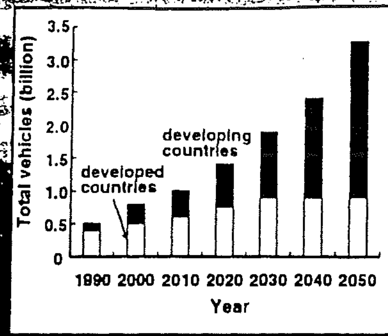


Figure 4: Prediction of automobile increase in major

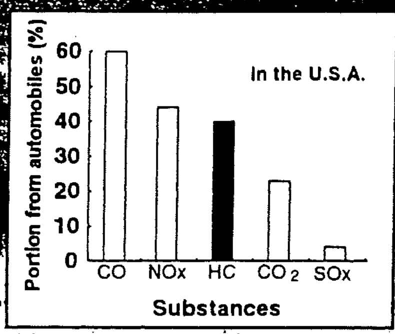


Figure 5: Pollutant substances caused by automobiles

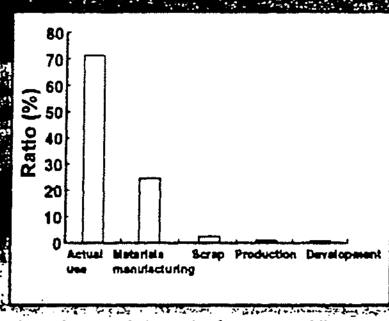
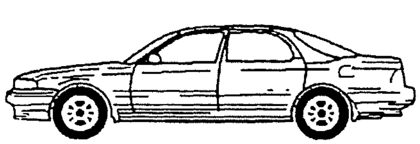


Figure 6: CO_2 emission ratios from automobiles development to actual use

Figure 7: Development trends of automobiles

ICV

- Realization of super cleaned vehicle by further reduction of HC, CO and NOx
- Realization of super high fuel economy vehicle



New energy vehicles

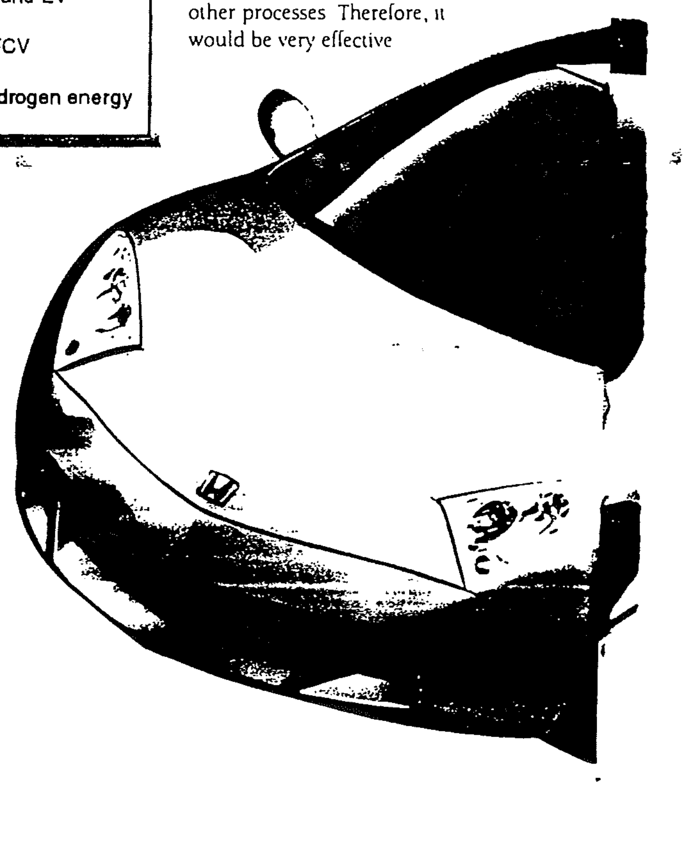
- Evolution and popularization of CNGV, HEV and EV
- Realization of FCV
- Research of hydrogen energy

the developing countries The huge number of vehicles in the developing countries will give a serious environmental load, and therefore, current technologies like engine control and catalyst should be transferred to developing countries to minimize the automobile emissions

Figure 5 depicts the ratio of total air pollutant emissions attributable to automobile exhaust in the USA Emissions of CO, NOx and HC come mostly from the exhaust emissions of automobiles The automobile industry, therefore, should make the utmost of efforts to reduce these pollutant substances One prominent measure to cope with the problem is the possible introduction of EV (Electric Vehicle), HEV (Hybrid EV) and FCV (Fuel Cell Vehicle) to the automobile market More imminently, pollutant substances from tail pipes must be reduced by improving fuel consumption and catalyst performance Concerning resource availability, there has been a strong warning indicating that petroleum resources may be depleted in the relative near future Before such a situation becomes more imminent, the oil market may suffer great turmoil A logical and appropriate step that the automotive industry could take to promote the development of vehicles powered by an alternative energy source[1]

Figure 6 shows the CO_2 emission ratios from automobile development to actual use The CO_2 emission ratio during actual use is extremely large compared to other processes Therefore, it would be very effective

"There is no one optimum solution, but one thing is for sure: the automobile must clean up its act"



to develop high fuel economy or low fuel consumption from a CO_2 emission point of view

Towards zero emission: The current and future trends of vehicles are shown in Figure 7. There are two approaches for the ICV (Internal Combustion Vehicle). One is a super clean vehicle by further reduction of HC, CO and NOx, the other one is a super high fuel economy vehicle. Approaches of new energy vehicles contain an evolution and popularization of CNGV (Compressed Natural Gas Vehicle), HEV and EV, a realization of FCV, and further research in hydrogen energy and storage system. The relationship between primary energies and various vehicles is shown in Figure 8. Automobile industries have now been developing various types of vehicles towards zero emissions[2]

Trends of the electric vehicle: In the wake of the Zero Emission Vehicle (ZEV) regulation, enforced by the California Air Resources Board (CARB) in September 1990, the development of EV has been further accelerated. Though the stated ratio required in the original document was 2 per cent in 1998, 5 per cent in 2001 and 10 per cent in 2003, the regulation was dramatically revised in 1996.

The revised ZEV standard required that the Big Seven automobile manufacturers in the USA and Japan – General Motors, Ford, Toyota, Honda, Daimler-Chrysler, Nissan and Mazda – must supply a total

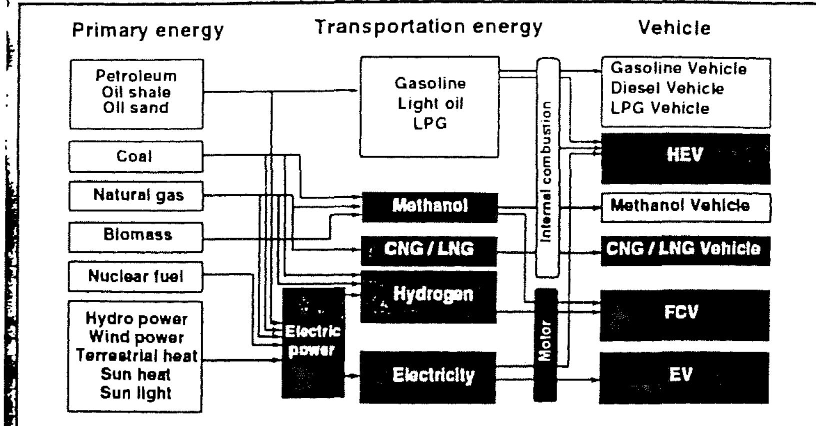


Figure 8: Relationship between primary energies and various vehicles

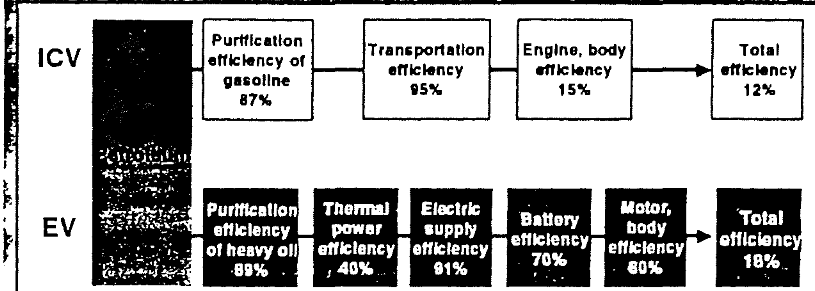
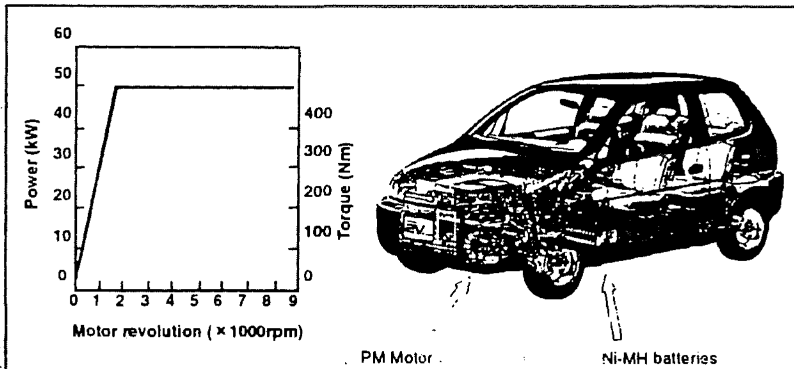


Figure 9: Comparison of energy efficiency between ICV and EV



Launched on the California in 1997

Max power	: 49kW	Total energy	: 27kWh
Max torque	: 275Nm	Total voltage	: 288V
Max efficiency	: 96%	Total weight	: 474kg

Figure 10: 'Honda EV Plus' and motor, battery specifications

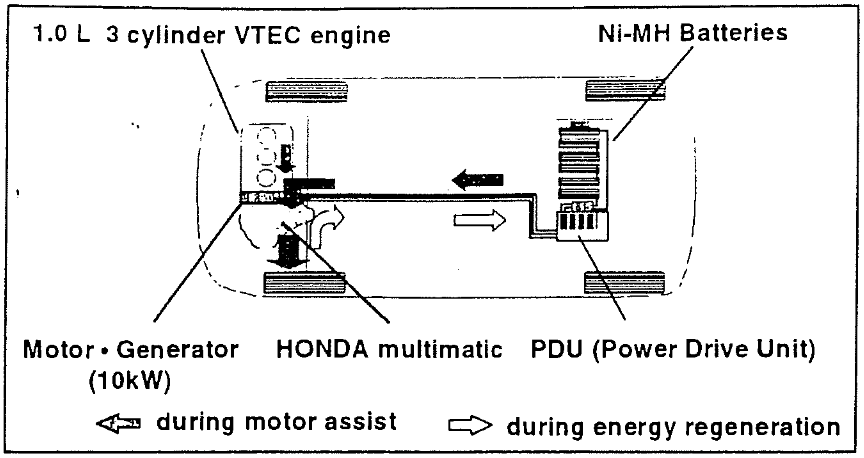


Figure 11: Honda HEV IMA system

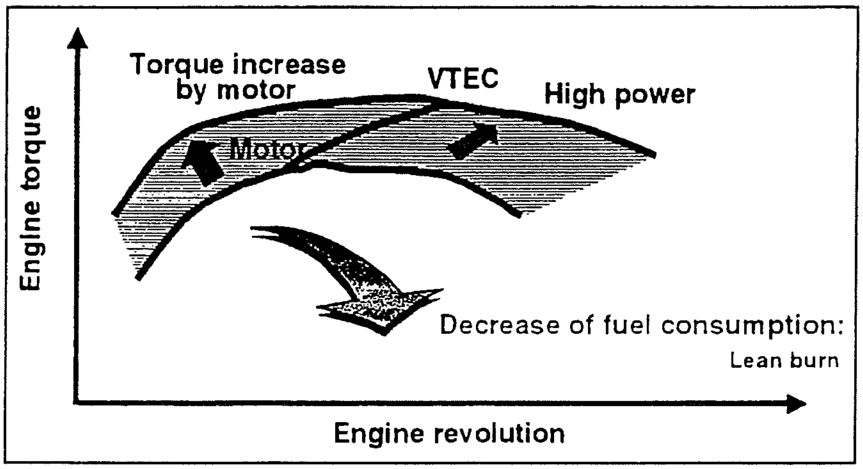


Figure 12: Approaches for energy efficiency increase by IMA system

In spite of zero emissions from the tail pipe, the EV indirectly generates CO_2 into the atmosphere This is attributable to the power generation where the amount of CO_2 emissions vary due to the method of generation Power generation using coal emits the highest level of CO_2, which is followed by oil, liquefied natural gas (LNG), and nuclear and hydraulic power methods This causes a vast difference in CO_2 emission from one country to another Based on the data, the CO_2 emission ratio of the EV over the ICV can be calculated The CO_2 emission due to the EV exceeds the ICV in Denmark where there is a large ratio of thermal coal power generation In France, where nuclear power generation has been widely utilized, the EV has a positive impact on the reduction of CO_2 generation

Honda has been delivering its EV Plus (shown in Figure 10) to California, USA, since early 1997 It has Ni-MH batteries and a permanent magnet synchronous motor that was developed for the EV[3,4] Further innovative developments including cost issue for batteries and motors will create more attractive EVs

Trends of the HEV: In the Japanese market, HEVs are gradually increasing in popularity and the demand will soon become large The reason for this expanding demand is due to the Japanese traffic

"HEVs are increasing in popularity and demand will become large"

,750 EVs to the State of California re a pilot demonstration program is / to be conducted by 2000 The state ernment and the seven automobile nufactures agreed to this under the morandum of Agreement (MOA) hough it has not been officially nounced, the quota requirements for 03 may remain unchanged while HEV d FCV will be regarded as an equivalent ZEV or near-ZEV

Electric energy – the secondary energy required by the EV – can be generated from many primary sources as shown in Figure 8 In this sense, the EV is more flexible than fossil-fueled vehicles (from an energy supply point of view)

Comparing the energy efficiency of the EV to the ICV with the assumption that the electricity used by the EV has been generated by thermal power, showed a total energy efficiency. 12 per cent for the ICV and 18 per cent for the EV, as shown in Figure 9 Even at the current condition, the EV is 1 5 times more efficient than the conventional ICV Further improvement in energy efficiency of batteries will widen the gap between the two

situation with many vehicles on the roadways causing heavy congestion Also, there are many consumers concerned with fuel economy and environmental issues Therefore, the reduction of CO_2 emission will be expected in accordance

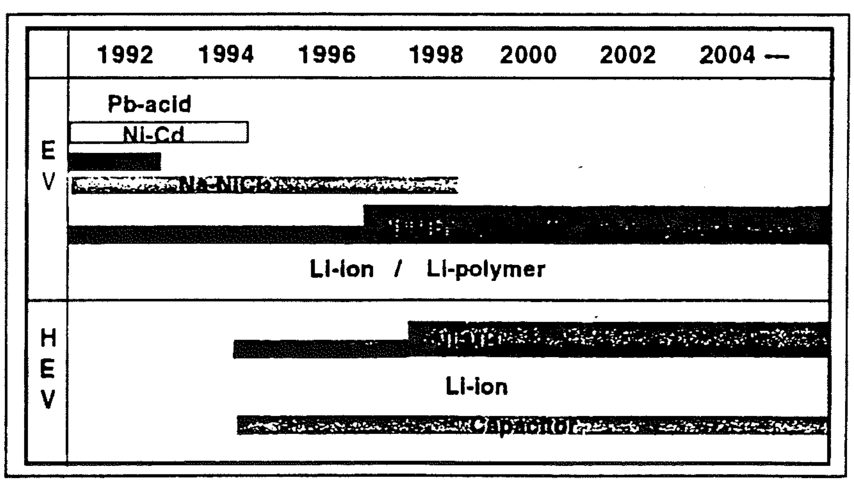


Figure 13: Development trends of energy storage for EV and HEV

Table 2: Development of FCV [illegible]

Fuel processor	Fuel stack components	System
CO clean-up	Air system	System volume and weight
System integration & efficiency	Stack performance and material cost	Thermal & water management
Start-up & transient operation	CO tolerance	**Infrastructure For methanol**
Catalyst cost		

Figure 14: Issues to be overcome for FCV

with the decrease in fuel consumption from an environmental point of view. The advantages of the HEV are that it has a similar usage as the ICV, and has no requirements for unique charging systems. The HEV is not a zero emission vehicle since it depends on fossil fuels. However, the HEV has much potential in saving fuel and decreasing emissions including CO_2.

Since late 1997, Toyota has marketed the Prius in the Japanese market. Furthermore, Honda and other car manufacturers have been developing more efficient HEV systems. For instance, within Honda, the new IMA (Integrated Motor Assist) system, shown in Figure 11, with a low fuel consumption of 2.86 l/100km, will be completed and delivered to several markets in 1999. The approaches for the increase of energy efficiency, or high fuel economy, will be attained by the integration of several technologies shown in Figure 12.

Highly specific power batteries or capacitors enable the rapid development of marketable HEVs. Since 1990, several types of energy storage systems have been developed worldwide for both EVs and HEVs, as shown in Figure 13. At this moment, the big issues for HEV development are creating an attractive system with a high-power energy system, such as capacitors, Ni-MH batteries and Li-ion batteries at a cost-effective price.

Trends of the Fuel Cell Vehicle (FCV): FCV is one solution to the post fossil-fueled vehicles. Currently, several systems have been proposed and are under development for the near future. Methanol, ethanol, natural gas and gasoline reforming PEFC (Polymer Electrolyte Fuel Cell) systems have been investigated in accordance with the availability of each fuel and its infrastructure, as shown in Table 1. Honda now focuses on the methanol reforming PEFC system. A gasoline reforming system shows no infrastructure barrier, however, the system will not meet a post fossil energy system, and the reforming energy efficiency of this system is inferior to that of methanol reforming. Hence, a gasoline reforming PEFC may not be realistic.

The most valuable advantages of FCV lie in zero emissions, less CO_2 and a high energy efficiency (compared to the ICV). Furthermore, there are no limitations for driving ranges and no special charging system required, which are needed for a pure EV. On the contrary, there are many issues to be overcome for the realization of FCV in the market, as shown in Figure 14.

As shown here, there are many issues to be resolved, but car manufacturers and other related suppliers, like catalyst companies, should be creating breakthroughs for this to happen in the 21st century. Some major car manufacturers, including Honda, are indicating that this realization will occur by 2003/4.[5] In the future, the FCV is expected to make up the majority of the vehicles on the market rather than the current ICV.

Conclusions: Automobile industries should develop multiple technologies to create a zero emission society as well as other industries. Air pollution caused by [illegible] emissions [illegible] the most concerning issue.

ICV should be developed as the ultimate super clean vehicle, like Honda's ZLEV, with minus emissions and super-high fuel economy vehicles. These approaches are very effective in the period prior to new energy vehicles.

New energy vehicles towards the 21st century should be developed from energy and environmental aspects. Electric power plant systems will be the most important technology area.

In particular, FCVs are developed as post ICVs, though there are many issues to be overcome with this. FCVs will appear in the beginning of 21st century, and for this reason, the infrastructure for fuel supply should be investigated as soon as possible.

HEV, EV and CNGV are also candidates for new energy vehicles. Drivetrain systems and energy storage technologies have been aggressively developed, especially Ni-MH batteries, Li-ion batteries and capacitors.

The relationship between automobile industries and component suppliers, energy suppliers, and governments will become more important to realize an intrinsic zero emission world. **E&H**

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This is based on a paper presented at Engine Expo 99 in Hamburg, Germany, 8-10 June 1999

70 mpg Hybrids

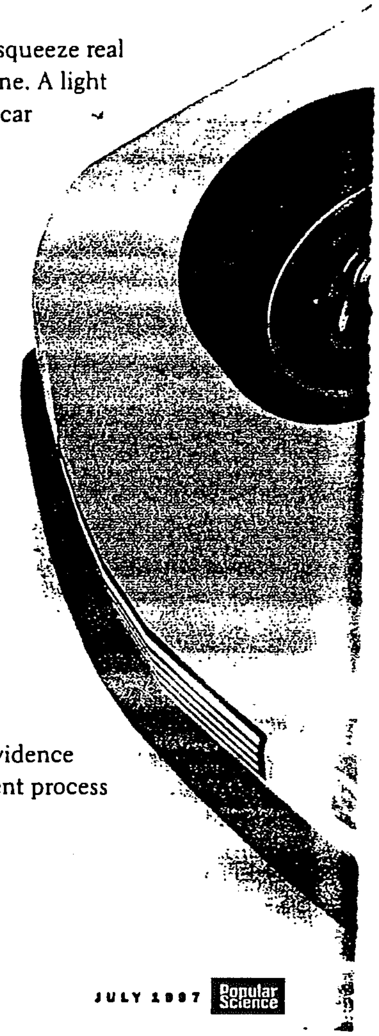
By Dan McCosh

Toyota takes the lead in the race to develop a superefficient car.

THE DEAD SILENCE of Toyota's new hybrid-drive car at a stop sign provokes a nearly overwhelming urge to turn the key and get the thing running again. The engine is, in fact, shut off—since logically there is no need to burn precious fuel at a standing stop, is there? But Americans are not used to logical automobiles. Here, the gas guzzlers even get the good supporting roles in blockbuster movies like *Jurassic Park*, with no small touch of irony, what with excessive fuel consumption producing carbon dioxide that threatens to return the climate to the dinosaur age.

Yet the car I'm driving uses a combination of electric and gasoline power to achieve nearly 70 miles per gallon—even in stop-and-go traffic. Aside from saving a few bucks on gasoline, the technical accomplishment required for such extreme fuel economy holds its own fascination: The two separate powerplants mesh in an intricate ballet, squeezing every last erg of energy from a drop of fuel. A touch of the pedal of the Toyota alternative engages the complex sequence needed to squeeze real mileage out of a tank of gasoline. A light touch on the throttle gets the car moving under electric power alone, supplied by a nickel-hydride battery pack. As the battery is depleted, the engine starts up with a chug, and at speed, the pistons become more audible. Ask for more power and the electric drive kicks in again, with a silent push for reasonable passing acceleration. The lack of a solid passing kickdown gear is sometimes disconcerting. But not as strange as braking, when the engine shuts down and you ghost to a stop. The sound of the future is mostly silence, after all.

The achievement is solid evidence that the ponderous development process

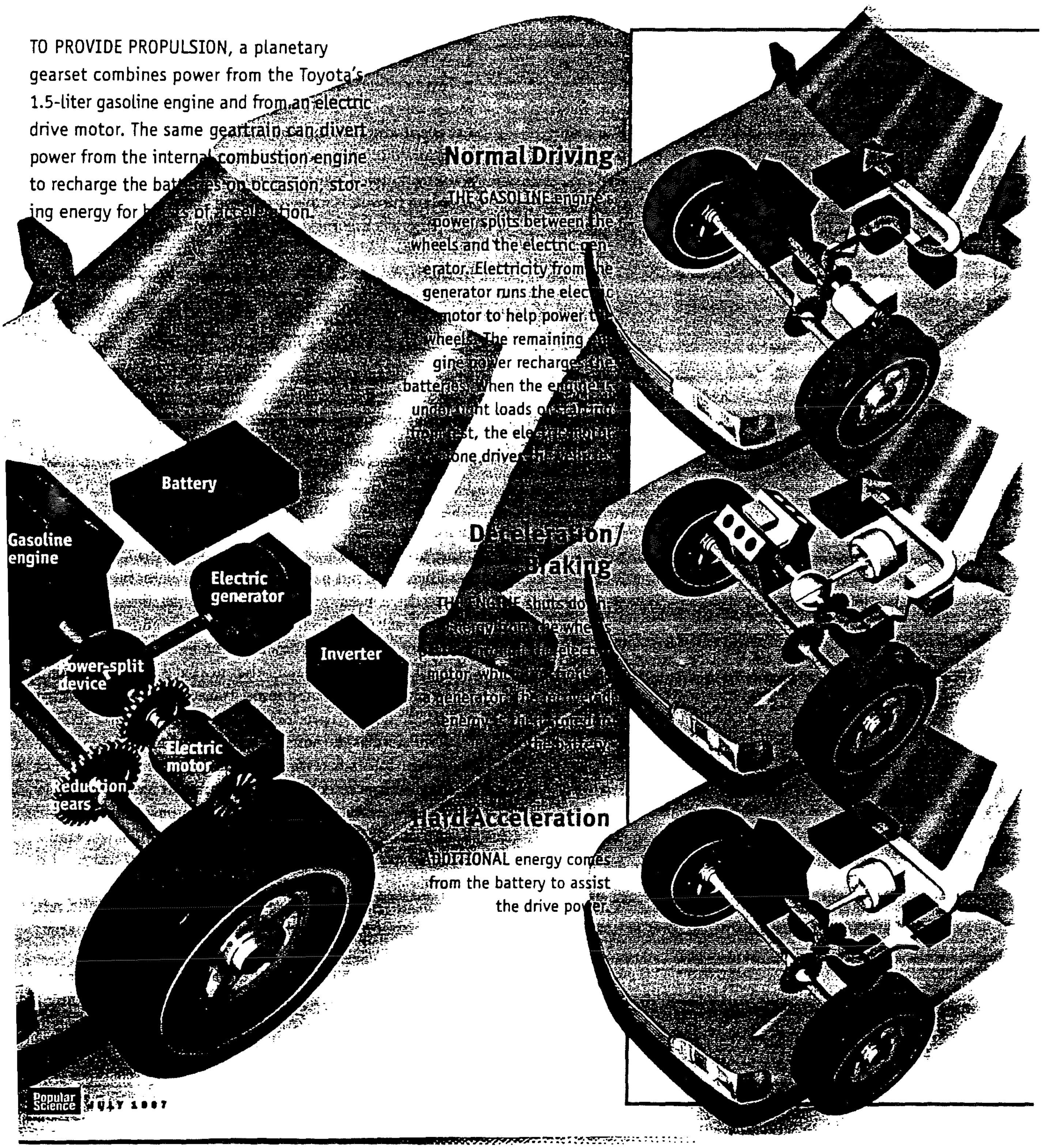


INFOGRAPHICS BY SLIM FILMS

that produces new automobiles is finally on the brink of a genuine technological breakthrough. Toyota says its Japanese customers will be able to buy this kind of fuel efficiency in a car this fall, and the ultra-efficient vehicle could appear in the United States as well within a few years.

The Toyota hybrid car adds another chip to the pile being wagered on a high-stakes gambit: the notion that technology will eventually save the family automobile. The hope is to develop ultrahigh-efficiency cars to offset at least partially the environmental problems associated with the rapidly growing population of cars on the world's roads.

The announcement that Toyota has such a supercar nearly ready for the showroom came as a surprise to the U.S. research effort. The American project had begun three and a half years ago, when three U.S. automakers formed a consortium that included the best and the brightest from the defense-oriented national laboratories to develop a full-size economically feasible car that could



TO PROVIDE PROPULSION, a planetary gearset combines power from the Toyota's 1.5-liter gasoline engine and from an electric drive motor. The same geartrain can divert power from the internal combustion engine to recharge the ba[illegible] on occasion, storing energy for [illegible]tion.

Normal Driving

THE GASOLINE engine's power splits between the wheels and the electric generator. Electricity from the generator runs the elec[illegible] motor to help power t[illegible] wheels. The remaining [illegible] gine power recharges the batteries. When the engine is under light loads [illegible] t, the ele[illegible] one drive[illegible]

Deceleration/ Braking

[illegible]

Hard Acceleration

ADDITIONAL energy comes from the battery to assist the drive power.

Three-Part Approach

FORD'S P2000 PROJECT CAR hopes to achieve some 70 mpg with a combination of light weight, a fuel-efficient direct-injection diesel powerplant, and a hybrid drive.

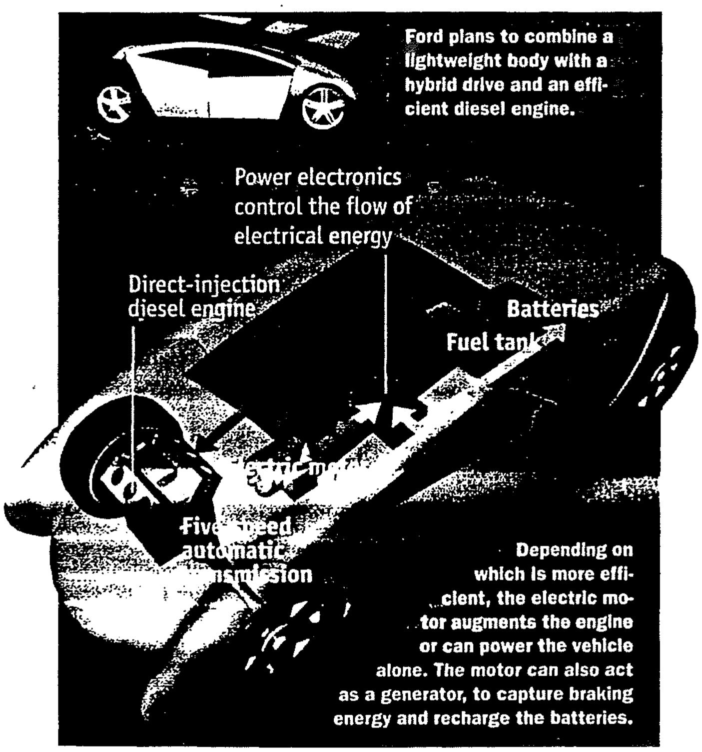
Aluminum construction, plus some components of exotic, lightweight materials, is expected to reduce the weight of the chassis without the powerplant by about 1,300 pounds—a gain that ultimately will be partially offset by the additional weight of the batteries.

Small direct-injection diesels, which gain about 25 percent in efficiency compared with older diesel designs, also are becoming relatively commonplace in Europe. New methods of injection timing reduce the noise and emission problems associated with this design. The Ford direct-injection engine uses variable-geometry turbocharging and four valves per cylinder to improve efficiency by a remarkable 43 percent.

The hybrid-drive component is expected to be developed in two stages. First will come a "low storage requirement" hybrid with a large starter-alternator that sometimes acts as an electric motor. This allows some energy to be recaptured while braking, and the diesel to be shut off at times.

A second stage adds a larger battery pack and drive motor. The additional power acts in parallel with the engine to add acceleration. Both systems incorporate an electronically controlled transmission and clutch.

Ford's plan is to have a running prototype powered by a diesel engine by the end of the summer. The hybrid-drive program is to follow.—*D.M.*



Ford plans to combine a lightweight body with a hybrid drive and an efficient diesel engine.

Depending on which is more efficient, the electric motor augments the engine or can power the vehicle alone. The motor can also act as a generator, to capture braking energy and recharge the batteries.

achieve about 80 mpg in day-to-day driving conditions.

Not the least of the goals was a kind of swords-into-plowshares recycling of high-tech research facilities that for the most part had been established to build atomic weapons and their delivery systems. Also put to risk was a bit of national pride, as the Partnership for a New Generation of Vehicles (PNGV) deliberately excluded offshore automakers, including the growing number with substantial research and manufacturing facilities in the United States, such as Toyota, Honda, and Mercedes.

This exclusion, along with the carrot of a growing market in underdeveloped countries where gas can cost from $2 to $5 per gallon, seemed to provoke an equally ambitious R&D program in Japan. The immediate result is Toyota's high-tech hybrid-drive car. When it arrives in Japan this fall, it will be arguably the most energy-efficient car ever to be sold to the general public, achieving an estimated 70 mpg in a five-passenger midsize sedan. That's roughly double the equivalent-size conventional car's fuel economy. Toyota's move—coming as it did seemingly from nowhere—is the automotive equivalent of Jeffrey Maier, the 12-year-old baseball fan who reached from the stands in the 1996 American League Championship Series and turned a sure out into a home run.

The game is not quite over yet, though. Toyota's high-mileage hybrid has so far been demonstrated only in prototype, and hasn't shown that it can meet U.S. emission requirements. It also is exclusively an exercise in extreme engine and drivetrain efficiency, with no reduction in overall vehicle poundage. The weight of the batteries in the hybrid-drive system adds several hundred pounds to the total vehicle, in fact. A dramatic weight reduction would add significantly to fuel efficiency; ultimately, Toyota will need such a weight loss to achieve the slightly more ambitious long-term goal of 80 mpg.

The American partnership, which expects to see at least a driveable prototype early this fall, aims at radical improvements in weight, aerodynamics, and rolling resistance, as well as the efficiencies of an alternative powerplant. The plan is to select the most viable and promising technologies this year, demonstrate initial prototypes by 2000, and develop production-feasible models by 2004.

Chrysler has demonstrated a hybrid prototype, and General Motors is testing a combination of a lightweight gas turbine and electric drive. Not so far along are Chrysler's announced plans to develop a gasoline-powered fuel cell. The first member of the PNGV to detail publicly its ultrahigh-mileage prototype was Ford.

This spring, Ford announced the general outline of this prototype, called the P2000. To save weight, the vehicle is made of aluminum and other lightweight materials. While a conventional Taurus-size car weighs 3,318 pounds, the P2000 will tip the scales at less than 2,000. The vehicle will be fabricated using relatively conventional high-volume manufacturing processes. To some degree, the effort is an extension of Ford's heavy investment in research in aluminum construction, which preceded the company's participation in the partnership.

Ford also has committed to a direct-injection diesel powerplant, similar to several high-efficiency diesels recently introduced in Europe, where fuel taxes favor diesel powerplants. In fact, Ford is already planning to introduce the diesel in Europe before the year 2000. Alone, the diesel promises a 43 percent improvement in fuel efficiency over gasoline engines of the same size. That sounds impressive, but it's no better than in the ballpark with contemporary production cars using similar engines.

Ford's P2000 program anticipates two hybrid-drive systems quickly following the diesel. First is a simplified system that uses a large starter-alternator to parallel the direct-injection engine, allowing it to be started and stopped at will. Second, a larger electric motor and battery pack add to the electric component and enhance the ability to recapture some braking losses. The anticipated program, including the weight reduction and hybrid drive, is expected to roughly match what Toyota claims it has already achieved.

Toyota's decision to develop a high-expansion gasoline engine rather than a diesel is partly based on worries that legislation further limiting diesels is on the horizon in many parts of the world, including the United States. Diesel engines produce particulates that are suspected carcinogens, and passing the stringent particulate test for passenger-car engines is already daunting.

Toyota's Atkinson-cycle engine is particularly compatible with hybrid drive, since its efficiencies are realized at a constant speed and load. The diesel selected by Ford is more flexible and is reasonably efficient even with conventional transmissions.

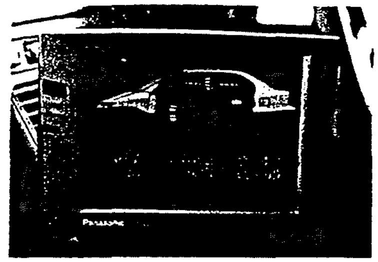
The most impressive achievement is Toyota's compact, light hybrid-drive unit, which takes up slightly less space than a conventional automatic transmission, even with the electric drive motor and the high-output alternator. Without the still-bulky battery pack, this package would come close to letting you simply drop the hybrid drive into an existing car. The key is the innovative coupling of the three basic components of the drive system through a single planetary gearset.

Estimates indicate that Toyota's entry will cost about $2,000 more than a pure gasoline engine. The additional expense mainly reflects the cost of the battery, power electronics, and electric drive motor. Elimination of the automatic transmission and torque converter offsets some of the additional cost of these components. That price is too high to recover the cost in the United States, where fuel is inexpensive, but the vehicle still will be attractive to motorists in most other countries.

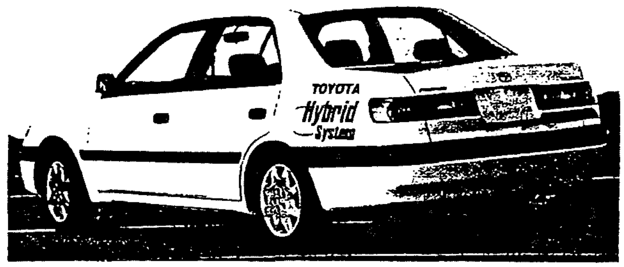
Toyota's remarkable powerplant takes some getting used to, but it is less of an alien experience than driving a pure electric car. Is this the car of the future? It's too early to tell, but the combination of efficiency, long range, low emissions, and reasonable cost add up to a bright promise that gas guzzlers will become dinosaurs once again. ◆

Hardworking Powerplant

LIKE MOST SUCH EFFORTS, Toyota's approach to creating a hybrid car combines the benefits of an onboard internal combustion engine—mainly the high energy content of gasoline—with certain features of electric drive that "level" energy demands while accelerating and stopping.



An electronic monitor graphically shows the hybrid drive and battery status; here, the motor has shut off while the engine and generator are at work.



For a day of test-driving with Toyota's new hybrid drive, a "mule" stands in for the actual body design, to be introduced this fall.

The gasoline engine is the main source of power. Toyota has developed an Atkinson-cycle engine, which gains as much as 38 percent in efficiency by using a short compression stroke and an exaggerated power stroke. Atkinson-cycle engines operate efficiently in a narrow rpm range. Adding an electric motor can boost efficiency by allowing the gasoline engine to operate in the high-torque zone as much as possible.

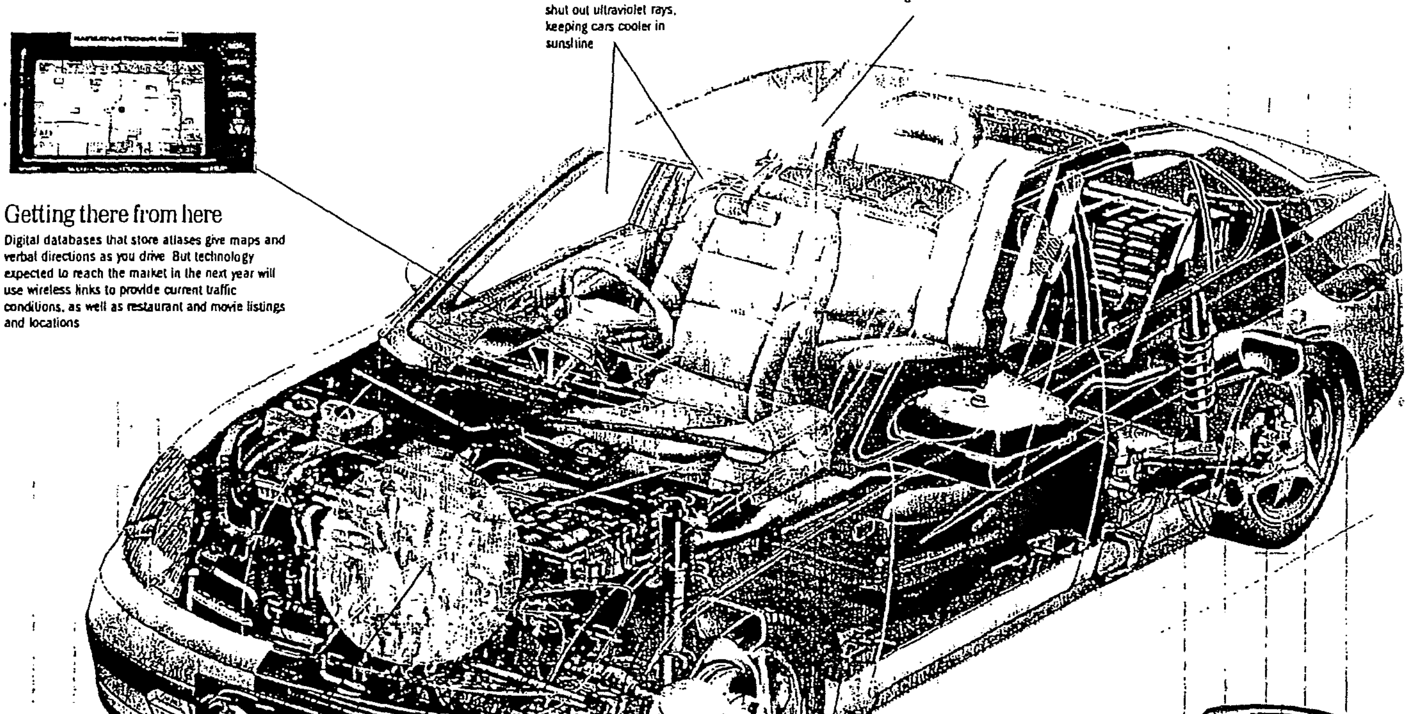
Toyota's driving cycle is as follows: When starting and at low speeds, the vehicle relies completely on the electric motor, drawing power from the batteries. As the vehicle approaches normal driving speeds, the gasoline engine kicks in, powering the car and recharging the batteries as well. Power bursts are achieved by combining the power of electric drive with the thrust of a piston engine. Decelerating, the engine shuts down and the charging unit converts some of the braking energy to electricity while slowing the car.

All of this interaction is achieved by a mechanical interchange through a planetary gearset. The main piston engine drives the planet ring; the alternator is on the sun gear and the permanent-magnet electric motor on the ring gear. The wheels are driven via the outer ring gear. This allows either motor or a combination of both to power the car, and even allows the piston engine to continue turning with the vehicle at a standstill, without a conventional clutch.—*Dennis Normile*

smart cars

Inside next year's car

Once relegated to the realm of concept cars and drawing boards, alternative fuel vehicles are gaining in popularity. A new generation of hybrid cars uses gasoline engines to generate electricity, cutting emissions and bypassing some of the limitations of all-electric cars. Here's a look inside the Toyota Prius, coming out next year, and at other technologies expected to reach the market in the next few years:



Getting there from here

Digital databases that store atlases give maps and verbal directions as you drive. But technology expected to reach the market in the next year will use wireless links to provide current traffic conditions, as well as restaurant and movie listings and locations

Where's the juice?

Power is provided by batteries when the car is starting, or at low speeds when the gasoline engine is inefficient

As you accelerate, the electric generator turns on the gasoline engine for more power.

At normal speeds, power from the gasoline engine runs the generator, which produces electricity

During full-throttle acceleration, batteries provide extra power to the wheels without the driver changing gears

Burning clean

Car designers are also looking to another fuel source – hydrogen fuel cells, which use fuels such as natural gas, ethanol, and methanol to create electricity. Their only by-products are heat and water.

Several car makers, including Daimler Chrysler and Honda, have developed cell powered concept cars. A design concept for Ford's P2000 fuel cell car is pictured above

Future technology is expected to allow smaller and lighter cells for a next generation of cars

Hybrid-electric engines: less fuel, less pollution

BY Hiawatha Bray GLOBE STAFF

Honda's new Insight is an odd-looking car, resembling a mutant Honda Civic. But the swoopy styling of the little coupe isn't nearly as adventurous as what lurks beneath the sheet metal.

For the Insight *(www.honda2000.com/insight/homepage.html)* is a new kind of car, one that combines electric and gasoline power under the same hood. The Insight really is a mutant – or rather, a hybrid. And it'll be joined on the market next year by Toyota's entry, a five-passenger sedan called the Prius that's already sold 28,000 units in Japan.

Both of these cars take a clever approach to car design that promises lower fuel consumption and less air pollution, while delivering a car that the typical consumer would actually want to drive. "It is a brand new technology on a brand new platform," says Mark Amstock, Toyota's national marketing manager for the Prius hybrid *(www.toyota.com/afv/prius/intro)*.

If all you want is a clean machine, you can go with an all-electric car powered by batteries. General Motors has been leasing its EV1 all-electric car *(www.gmev.com)* since 1997. But so far, only a few buyers have signed on. Consumers have rejected a car that has to be plugged into an electric socket every 60 miles, for a recharge that can take up to three hours.

So engineers decided on a different tack – a combination of electric and internal-combustion power, where each type of motor would help to overcome the deficiencies of the other. By adding an electric motor, a hybrid gets good acceleration without having to burn as much gasoline. By keeping a gasoline motor, the hybrid can keep its batteries fully charged at all times. It can also use a far smaller battery pack, weighing around 100 pounds instead of the 1,200 pounds of the all-electric EV1.

In a hybrid car, you'll find a small gasoline or diesel engine with a transaxle linking the power plant to the front wheels. So far, so ordinary.

But in the Toyota Prius, an electric motor and a generator are attached to the transmission. The generator, driven by the car's 58-horsepower gasoline motor, recharges the 135-pound battery pack, and can provide power for the 40-horsepower electric motor as well.

A sophisticated computer system constantly regulates the gas engine, electric motor and generator, using each in the most efficient way possible. Say you're pulling away from a stoplight. That requires lots of torque – the actual turning power delivered by an engine. As it happens, electric motors provide torque more efficiently than a gas engine. So the Prius will disengage the gas engine from the transmission and feed all its power to the electric generator. That power goes to the electric motor, which transmits it through the transaxle to the wheels.

But once the car is rolling along at a good clip, it's more efficient to rely on the gasoline engine for turning the wheels. The electric motor is shut off and the generator is used if the battery needs topping off.

Honda's Insight does it all a bit differently. The Insight has no generator, just an electric motor powered by a battery. Once again, the electric motor kicks in under those driving conditions that suit it best.

But how does the Insight recharge its battery without a generator? In fact, it does have a generator: the electric motor itself. Run an electric motor in reverse, and it generates electricity. So when the Insight is cruising, its electric motor

ENGINES, Page H8

Hybrid electric engines: less fuel, less pollution

■ ENGINES
Continued from Page H4

can recharge the car's battery.

Both the Prius and the Insight take advantage of this principle at every stop light, in a technique called "regenerative braking." Tap the brake, and the electric motor of the hybrid connects to the transmission. The motor runs in reverse, generating electricity and recharging the battery. Meanwhile, the car slows down as its forward momentum is used to spin the electric motor-turned-generator.

Regenerative braking is vital to a hybrid's efficiency. Traditional brakes just discard the energy of a car's momentum, turning it into waste heat. Hybrids still use traditional hydraulic brakes as well. But their regenerative braking systems let hybrids capture some of the car's lost momentum, then reuse it to get the car rolling again.

Hybrid cars still burn fossil fuel, just not as much as traditional cars. Toyota's Prius, somewhat larger than the company's Corolla compact sedans, gets about 55 miles per gallon. The Insight, a two-passenger coupe, should deliver more than 60 miles per gallon.

These fuel savings also mean a sharp reduction in greenhouse gas emissions. That's why Dan Becker is such a fan. Becker, director of the global warming and energy program for the Sierra Club, reckons that over its lifespan, a typical Ford Taurus sedan will dump 64 tons of carbon dioxide into the Earth's atmosphere. A Prius would contribute only 27 tons.

Hybrid cars still burn fossil fuel, just not as much as traditional cars.

And unlike pure electric cars, the user of a hybrid doesn't have a rubber band on his bumper, dragging him back home every 60 miles or so to recharge his ride. With a hybrid, says Becker, "You can do everything you want to do, anywhere you want to do it."

Becker may be even happier in a few years, if scientists in Japan and the United States find ways to abandon gasoline for cleaner fuels. The ultimate goal is a car powered by a fuel cell; a system in which hydrogen and oxygen are mixed together in the presence of a chemical catalyst. The only byproducts of this reaction are water and electricity, so a fuel cell could be used to drive ultraclean electric cars

But nobody expects to see fuel cell cars for another decade. Fuel is a big problem; to carry enough hydrogen, the gas must be stored under high pressure, in a big heavy steel tank that uses up much of the car's carrying capacity. Besides, there are no hydrogen filling stations on the nation's street corners. So for now, gasoline-powered hybrids are likely to be the energy-efficiency champs.

That's good news for the Japanese. Inspired by the high gas prices of their homeland, Japanese firms have taken a big lead in hybrid development, with American automakers lagging years behind. GM, Ford, and DaimlerChrysler have yet to announce when they'll start selling hybrids. But the Big Three have joined with the federal government in a research consortium that's developing hybrid technologies.

Thomas Kizer, director of powertrain and electrical engineering DaimlerChrysler, said his compa is focusing on mild hybrids, or "n brids." These will be cars and truc where a traditional gasoline or die engine still does the great bulk the work, using an electric mo only for the occasional assist.

"What we're looking for is proper balance between the cost a the benefit," said Kizer.

Both Honda and Toyota thi they've already found it. Soon we see if American consumers agree.

Hiawatha Bray is the Globe's technology reporter. His column, Upgrade, runs every Thursday in the Business section. His e-mail addre is bray@globe.com.

Wall Street Journal 7 19

AUTOS

A Little Gas Fuels Hope for a New Type of Electric Car

By FREDERIC M. BIDDLE
Staff Reporter of THE WALL STREET JOURNAL

Can Japanese auto makers overcome the previous backfires of electric cars in the U.S.?

Toyota Motor Co., one of the world's largest car makers, is gearing up for the U.S. launch of a next-generation "green" car called the Prius. Already sold in Japan, the Prius will roll out here by the middle of next year. On a much smaller scale, rival **Honda Motor Co.** plans to introduce its own model, the Insight, in December.

What makes these cars different is that they are hybrids, running on both a gas engine and a nearly noiseless electric motor. With a computer monitoring conditions, the gas engine in the Prius kicks in to give the car more power when needed. At slower speeds or when the car is idling, the Prius's electric motor usually runs solo.

Among Toyota's print ads for the Prius: "It's gas, it's electric, boogie-oogie-oogie-oogie," and "Gasolectric? Electroline?" Another: "Two identities, no crisis."

With a big cabin, the Prius (pronounced PREE-us) will get at least 55 miles a gallon at freeway speed, Toyota says, and travel 725 miles between fill-ups—farther than nearly any car on the road today. Pricing the Prius around $20,000 or more, roughly the same as its best-selling Camry, Toyota aims to sell as many as 20,000 cars in its first year here and in Europe, where the car will arrive in mid-2000.

Honda says the Insight, which will get more than 70 miles to the gallon, will be priced at less than $20,000. The company expects to sell fewer than 5,000 models a year in North America.

Toyota's Prius *(top) and Honda's Insight are gas/electric cars that promise 55 to 70 mpg—and no plugging in*

The timing for all this could hardly be worse. The new cars will arrive smack in the middle of a sport-utility vehicle craze, when American drivers are in love with some of the biggest, most gas-guzzling vehicles since the '70s oil crisis. And the projected sales of hybrid cars will barely move the needle of the overall U.S. car and light-truck market, which is zooming toward record sales this year of more than 16 million vehicles. Still, it's progress. Since the internal-combustion engine became the industry's choice, way back in the days of the Tin Lizzy, only a few thousand all-electric vehicles have been sold in the U.S.

The modern generation of electrics, such as **General Motors** Corp.'s teardrop-shaped EV-1, have flopped with consumers. They're largely relegated to city government and utility fleets. Not only can electrics barely complete a typical Southern California commuting day before running out of power, they typically cost more than $30,000 and have to be leased because no viable resale market exists.

In April, Honda canceled its EV-plus electric car. And in October, **Edison International** says, it will close its Edison EV unit, which installs and maintains most of the electric-charging stations in California and Arizona, partly citing the outlook for electric cars. "We just don't see significant volumes," says Gloria Quinn, a spokeswoman.

"Those two things in my mind indicate the consumer has strongly spoken," says Thad Malesh, a senior consultant at J.D. Power & Associates, Agoura Hills, Calif. While GM, **Ford Motor** Co. and **DaimlerChrysler** AG are still sol-

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Gas Fuels Hope for Electric Cars

Continued From Page B1

diering on with electric vehicles, none foresee a sales breakthrough.

That's where the hybrids may come in. Auto makers argue that they represent a compromise between the "zero-emission" vehicles California regulators want and the cheap, practical transportation machines consumers demand.

To convince consumers that driving a Prius doesn't feel that different, Toyota is taking the unusual step of allowing Toyota owners in 12 cities to take one-month Prius test drives in return for feedback.

Toyota needs to persuade two audiences: consumers and regulators. Like its rivals, Toyota wants California and Northeastern states to encourage low-emission hybrid cars, arguing that drivers will accept them more than no-emission electrics.

Among California test-drivers, the Prius has gotten good grades. "I could use this as my first car," says Cathy Malena, 44 years old, who with her husband, Len, has driven the Prius on short trips and 110-mile round-trip commutes from their Trabuco Canyon, Calif., home. "I'd absolutely take this car over the Camry," of which she has owned three.

"It'll probably change driving habits," says David Nelson, a 59-year-old Yorba Linda, Calif., carpenter who describes himself as "no environmentalist." The Prius's large cabin and snub nose produced the only serious complaint from Mr. Nelson, who says that on a drive to San Diego, the wind may have caused the car to oversteer. "On long trips, I'm not sure I would take it," he says.

The often-quiet ride is what mainly sets the Prius apart from other boxy Japanese compacts, test drivers say. At idle and certain starting conditions, the Prius has no "idle roar" since only the battery is running. At hard acceleration, the gas engine kicks in, producing normal rumble. Decelerating, the gas engine sometimes cuts off again, making the car quiet as a golf cart. At times, passengers have told him the Prius can "feel a lot like riding a monorail," Mr. Nelson says.

Not being able to judge speed by the sound of the engine "takes a little getting used to," says Kirk Saunders, a 40-year-old architect in Laguna Beach, Calif., who estimates he got no better than 34 miles per gallon in primarily city driving. Asked about that, Toyota says mileage is much higher on the freeways.

Since the Prius doesn't require stops for recharging, whenever shopping-mall spectators approach his Prius, says Mr. Malena, "I get to tell them there's no plug."

Vith Classified Advertising
Automobiles FRIDAY, OCTOBER 1, 1§
The New York Times

ıUTOS ON FRIDAY/Technology

Looking Under the Hood of a Hybrid Honda

By MATTHEW L. WALD

WASHINGTON

HONDA and Toyota started with the same concept, an automobile powered by both an internal-combusı on engine and an electric motor, and each mpany will begin shipping such hybrid .rs to dealers in a few months, the first of ıat environmentalists hope will be a flood innovative cars from companies around e world. But the two Japanese companies at will be the first to market have assem-ɔd similar ingredients into products as dif-rent as a potato chip is from a French fry.

The Honda Insight will be in showrooms December, the first mass-produced hy-ids offered for sale in this country. Two-aters vaguely reminiscent of the Honda ‹X, which went out of production in 1992, ɔy will have an E.P.A. fuel economy rating more than 70 miles a gallon, the company id, and will sell for less than $20,000, in-ıding amenities like keyless entry and wer windows (although with only a man-l transmission, at least for now). With a nge of 600 to 700 miles on a 10.4-gallon ık of plain old unleaded gasoline, they oid the electric car's dilemma of where to :harge and then, after 100 miles or so, ıere to recharge again, and then again.

The Toyota Prius, already on sale in Ja-n and due here later in the 2000 model ır, is a four-seater that will go more than miles o ı a gallon of gas, the manufactur-says. The car will sell in the low $20,000 ıge — more than a Corolla, which is about same size, and less than a Camry.

Vith these pioneering hybrid vehicles in marketplace, a new question presents it-f: How electric is a hybrid?

n a sense, it does not matter, since both far more fuel-efficient than existing 's, and the Insight is substantially clean-too. Bill Richardson, the Secretary of En-y, said in a statement that because of ir cleanliness, fuel efficiency and per-mance, "hybrid cars can revolutionize automobile industry."

3ut engineers' strategies differ. The In-ıt is a 73-horsepower combination, of ıch 67 is produced by the gasoline engine l just 6 by the electric motor. The 98-sepower Prius has a balance of 58 horse-/er in the engine and 40 in the motor. The us runs on electricity alone at low eds; the Insight's motor is never more n a helping hand for the gas engine.

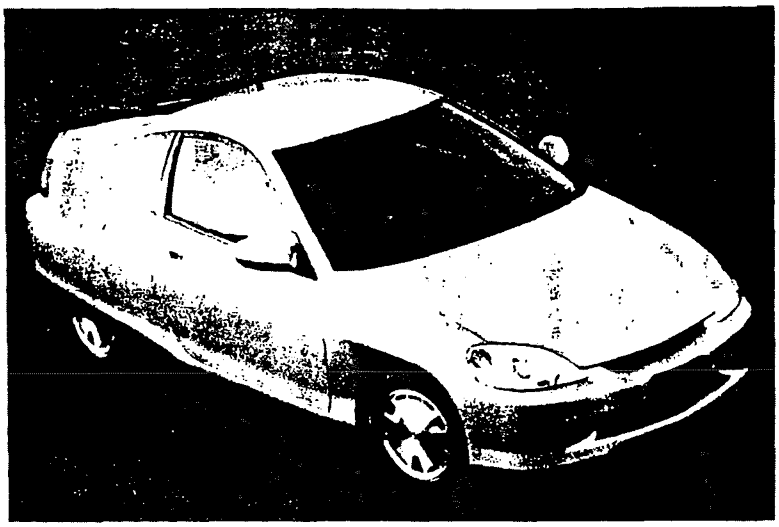
The Prius represents not only a some-ıt different use of technology, but with four doors and four seats, it is also aimed at a different market.)

A third approach, a car with an electric-only system for turning the wheels, and a tiny gasoline engine for charging the batteries, has caught the attention of engineering students in university competitions, because of its high potential for efficiency and cleanliness. (Engines running at constant speed can be tuned to run very cleanly.)

The approach taken by Honda is what some engineers call a "mild hybrid," a vehicle with a small, supplemental electric system that gets its charge by absorbing energy from the gas engine when the car is not accelerating, or in absorbing mechanical energy and converting it to current when the driver slows down. (Honda designers say that mild hybrid is a vaguely derisive term that originated with electric utilities disappointed that the vehicle will not be charged from a wall socket.)

Regardless of its etymology, the mild hybrid is a conservative idea, because the Insight can be driven even if the electric side fails — although it would perform "like a dog," one Honda executive said.

But it also shows the value of incremental steps. Dan W. Reicher, an assistant energy secretary who drove around Washington in one of the half-dozen Insights that Honda brought here last week, said admiringly, "It was remarkably unremarkable."



Honda's Insight, above, and Toyota's Prius share a concept, but they work differently.

The car demonstrates some neat technological tricks that could show up in other hybrids or in other conventional vehicles.

One is what Honda calls "idle stop," which means that when the speed slows to less than 5 miles an hour, the engine shuts off. Push in the clutch and throw the shift lever into first gear, and the engine starts again. It is running smoothly before the driver can let the clutch out.

That is made possible by the nature of the electric motor, which is doubling as a starter. In a conventional car, the starter is a whiny little motor that drives the teeth of the flywheel. But in the Insight, and possibly in conventional gasoline cars to come, it is a big flat disk, just two and a third inches wide, mounted between the engine and the transmission. The rotor (the part that turns) is the driveshaft of the car; the stator (the part with the magnets that push the rotor) forms the outer circumference. Size and configuration make it more powerful and less noisy than a conventional starter.

Continental Teves, a leading supplier of parts to the auto industry, has been trying to sell such a system to car companies for their conventional gasoline models.

The Insight's engine is also a refinement. Displacing 995 cubic centimeters, or less than the motor of a big motorcycle, it has a plastic intake manifold and valve cover and an oil pan of magnesium, which is 35 percent lighter than aluminum. To reduce friction, it has four valves per cylinder and an offset crankshaft to minimize side forces on the piston as it descends.

All technologies would work well on a conventional car, as would a smooth plastic bottom, another Insight refinement, and a total weight 47 percent less than a similarly sized Civic hatchback's. In fact, Honda says the Insight gets 85 percent better mileage than the Civic; of that, 30 percent is due to a lighter, more aerodynamic body. Another 30 percent is because of engine changes, including four valves per cylinder and the offset crankshaft. But the engine can also be smaller, because the electric motor meets part of the peak power demand.

And that is where even a mild hybrid makes a difference. The gasoline engine can be smaller because where it is weakest — at low engine speeds and high demand, as when the stoplight turns green — the electric motor is powerful, with high torque, or pulling power, even at low speeds. The dashboard of the Insight has a small display that indicates whether the electric system is charging or assisting; whenever the gas engine is turning slowly, at times when anyone used to a manual transmission would want to downshift, the dashboard indicates that the electric assist is running, and not to shift down. The motor is programmed to provide slightly more help in the intervals between cylinder firings, to reduce the vibration inherent in a three-cylinder engine, and a driver who resists the temptation to downshift will achieve high fuel economy.

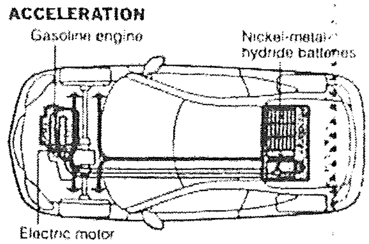
On a drive through the rolling hills of Maryland north of Washington, the car climbed smoothly at 30 m.p.h. even in fifth gear. At stop signs, downshifting engaged the electric motor in recharge mode, recapturing the mechanical energy.

Mr. Reicher, of the Energy Department, who oversees development efforts for more exotic vehicles, gave the Insight high praise for its ordinariness, which in this case may mean its marketability. "I've driven many, many Hondas," he said, "and it drove like a nice Honda, like a regular car."

Power From 2 Sources

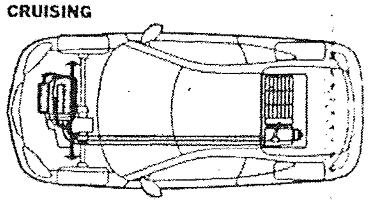
The 2000 Honda Insight, the first hybrid-power car sold in the United States, has both a small three-cylinder gasoline engine and an electric motor. The motor excels when the gas engine is weakest; in quick starts from a standstill, for instance.

ACCELERATION



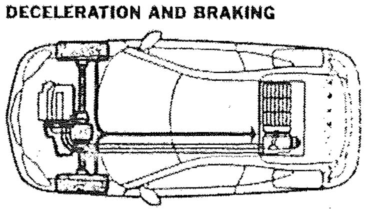
During acceleration, both the gasoline engine and the electric motor drive the wheels. Electricity for the motor is stored in the nickel-metal-hydride batteries.

CRUISING



At steady speeds, the wheels are driven by the gasoline engine.

DECELERATION AND BRAKING



The electric motor acts as a generator. Mechanical energy from the transmission is converted into electrical energy, which is used to recharge the batteries.

IDLING

When the car is coming to rest, the gasoline engine does not idle; it shuts down. When the driver puts the car in gear and lets out the clutch, the electric motor works as a starter, instantly restarting the gas engine.

Source: Honda

The New York Times

Honda Insight hybrid makes heavy use of light metal

IAN MORTON
Automotive News Europe

TAKANEZAWA, Japan — Honda has made extensive use of aluminum in the development of its new Insight hybrid car.

The Insight's 1.0-liter low-friction VTEC gasoline engine is of all-aluminum construction and incorporates aluminum components such as the rocker arm. The engine works in conjunction with an ultrathin electric motor and nickel-hydride battery pack.

The Insight's drivetrain weighs 57 percent less than that of a conventional hybrid model, said Honda.

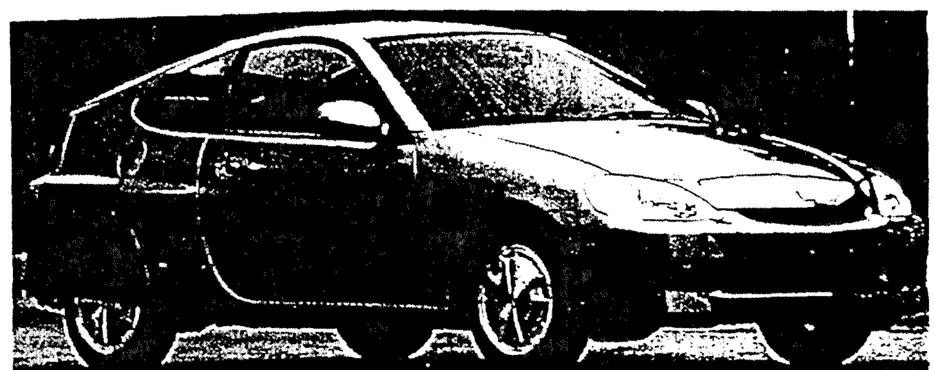
The Insight also boasts an ultralight aluminum body. Basic structural elements are made of extruded aluminum that uses novel hexagonal and cross-shaped section frames.

Rigidity and crash safety are strengthened by the use of joints in die-cast aluminum with moldings designed to integrate several functions, reducing the number of parts. A small number of steel bolts are used at key locations.

The Insight's aluminum body is 47 percent lighter than the steel-bodied Honda Civic.

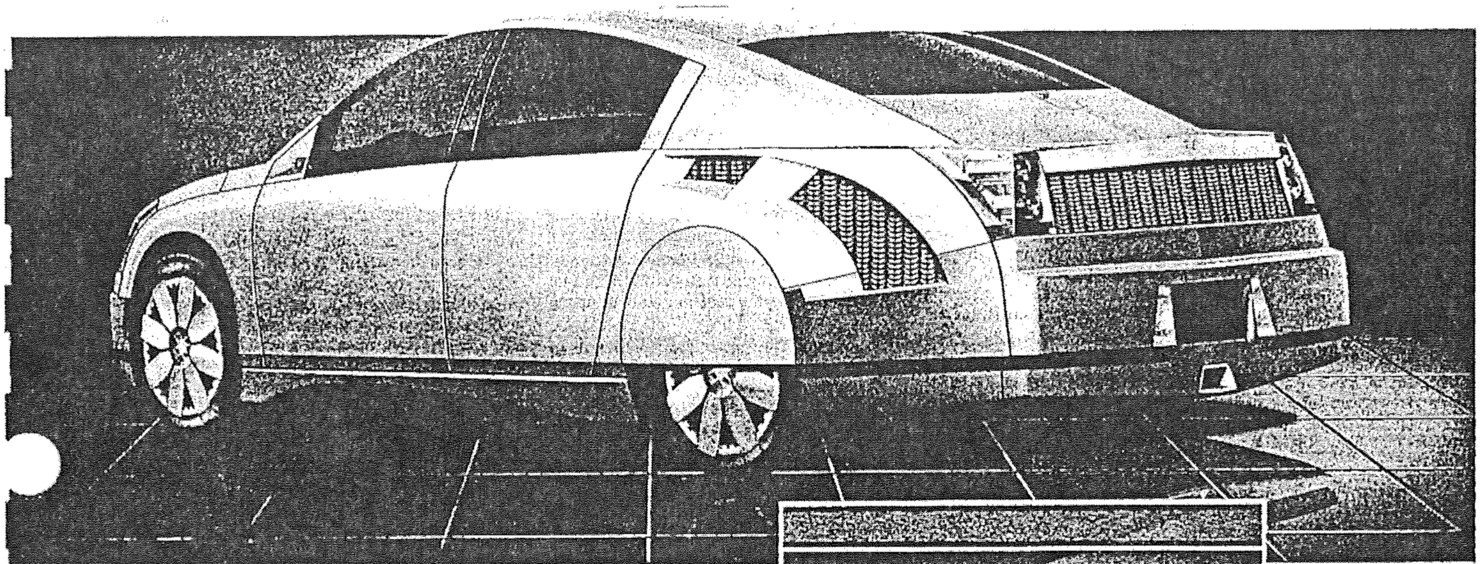
The Insight's aluminum suspension components are 30 percent lighter than the equivalent steel parts from the Civic. Other small aluminum parts such as the accelerator pedal, wheels and suspension arms save another 176 pounds.

The Insight has been developed for relatively large production runs. The Takanezawa factory is gearing up to make 8,000 units a year initially but can increase that figure according to demand. AN



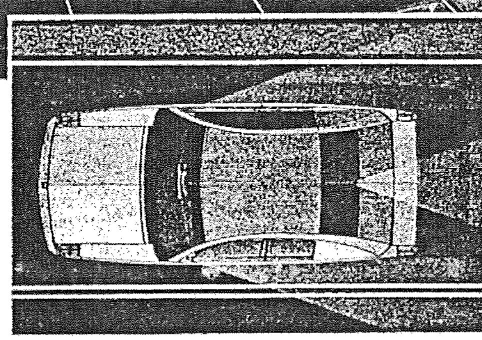
The Honda Insight's aluminum body is 47 percent lighter than the steel-bodied Honda Civic.

New York Times 1/1/2000



Detroit Plays Catch-Up In Race for Hybrid Car

With Fewer Subsidies, Japan Is Ahead



GENERAL MOTORS The Precept, above, G.M.'s experimental hybrid car, has door-mounted cameras, left, that replace rear-view mirrors.

By KEITH BRADSHER

DETROIT, Dec. 31 — With hundreds of millions of dollars of private and federal research work behind it, the **General Motors** Precept, an experimental model to be introduced here on Jan. 9, is probably the most expensive single car ever built. Yet it is still a lot of car for the money.

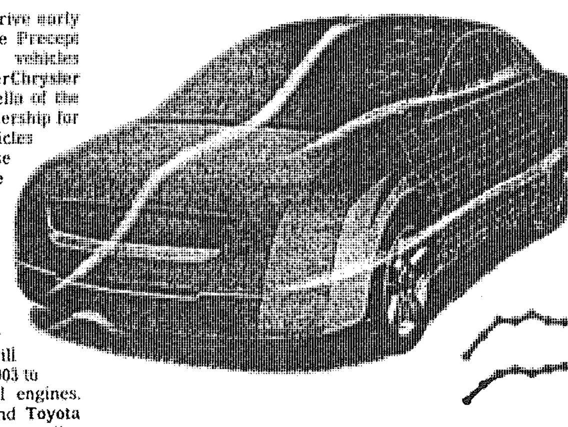
In place of side-view mirrors, which cause a lot of wind resistance, it has tiny cameras, mounted on the front doors, that send images to the dashboard. Rather than the smooth, rounded contours commonly associated with aerodynamic design, carefully angled body panels are designed to give the x-passenger Precept far less wind esistance than a Corvette sports car. And instead of a gasoline engine, the car has two electric motors, batteries under the seats and a rear diesel engine to charge the batteries and provide additional power and range.

These features, which produce remarkable fuel economy of almost 80 miles a gallon, are expected to influence what Americans will drive early in this new century. But the Precept and similar experimental vehicles from **Ford Motor** and **DaimlerChrysler** being built under the umbrella of the government-sponsored Partnership for a New Generation of Vehicles face huge obstacles that raise serious questions about the costly partnership between Detroit and Washington.

For one thing, the Big Three have all focused on diesel-electric hybrid cars. Yet federal and state environmental regulators have just adopted new rules for tailpipe emissions that will make it very difficult after 2003 to sell automobiles with diesel engines. Meanwhile, **Honda Motor** and **Toyota Motor**, operating with much smaller government subsidies, have already begun mass production of small high-mileage cars that combine gasoline engines and electric motors, leaving Detroit scrambling to catch up.

Manufacturing costs for all hybrid

Continued on Page 5



FORD The Prodigy, left, which is also experimental and will be introduced this month, comes with an air-conditioning system that shuts down whenever the car stops.

Detroit Is Playing Catch-Up in Race for a Hybrid Car

Continued From First Business Page

cars, including the Japanese models, are steep, so selling them at competitive prices remains a money-losing proposition. Perhaps most daunting of all, there is little sign that Americans want high-mileage cars in an era of relatively low gasoline prices and rising national prosperity.

The combination has left Detroit executives alarmed by a new competitive threat from Japan, frustrated by what they see as conflicting strategies among government agencies and struggling to justify further investments in cars like the Precept. But auto industry leaders here say that despite the problems, they intend to continue pouring money into high-technology cars, mainly to protect themselves in case gasoline prices soar again someday.

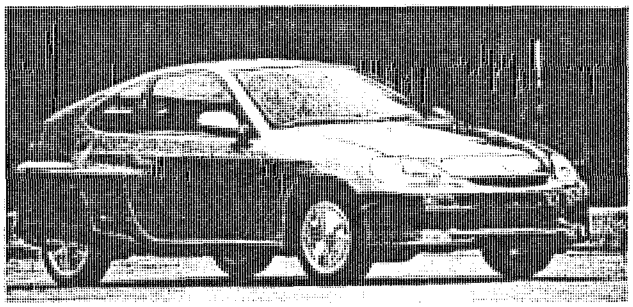
"We'd better be prepared to deal with it," said Harry Pearce, G.M.'s vice chairman. "You don't revolutionize your industry overnight."

The biggest embarrassment for G.M., Ford and DaimlerChrysler is that Honda and Toyota have beaten them to the market for hybrids. The Clinton administration has given $1.4 billion over the last five years to national laboratories, universities, auto parts manufacturers and Detroit automakers to help in the building of a few experimental models. Yet Japanese automakers, who were excluded from the program, have been able to put working hybrids on sale first.

The Honda Insight, which went on sale on Dec. 15, starts at $19,295, and gets 61 miles to the gallon in the city and 70 on the highway. Toyota plans to start selling its bigger Prius next summer for a little over $20,000, and predicts that its car will approach a combined 50 miles to the gallon.

Honda and Toyota officials don't mind rubbing it in. "We always see our competitors talking about their projects as soon as we hit the market with a real product," said Robert Bienenfeld, Honda's manager of sales and marketing of alternative-fuel vehicles.

The Japanese government has provided a small subsidy for the cars. Japanese car buyers who choose the new-technology automobiles receive a $3,000 rebate from the government. The Clinton administration proposed a similar program in the United States last winter. It was combined with tax-cut proposals in Congress and never made it into law, but is expected to pass once G.M., Ford and DaimlerChrysler have cars that can use such subsidies.



The Honda Insight starts at $19,295, and gets 61 to 70 miles to the gallon. "We always see our competitors talking about their projects as soon as we hit the market with a real product," a Honda executive said.

While Honda and Toyota executives refuse to discuss their costs, auto analysts say that both automakers will be losing money on every car they sell. But with Honda planning to sell only 4,000 Insights in the United States next year and Toyota expecting to offer just 12,000 Prius cars in the 2001 model year, neither company's costs will be exorbitant.

Yet as Detroit executives have been quick to point out, the Insight and Prius fall far short of the roomy, high-performance sedans that G.M., Ford and DaimlerChrysler hope to produce someday. The Insight, for example, is essentially a two-seat, very lightweight aluminum car with a small gasoline engine that does most of the work. As in most hybrid cars, the engine shuts off when the vehicle stops; once the driver touches the accelerator, a small electric motor and modest batteries get the car moving again while the gasoline engine turns back on.

How many Americans will really want to buy high-mileage cars?

Toyota has taken a different approach with the Prius, which closely resembles a Corolla from the outside. Compared with the Insight, the electric motor and batteries provide a much greater proportion of the car's overall power. But the Prius, because it is heavier, manages to achieve only slightly better mileage than the smaller Chevrolet Metro. The Prius, in essence, is a compact car with fuel economy a little better than a subcompact's.

Despite these cars' shortcomings, Detroit automakers, particularly G.M., still feel pressure to match the Japanese entrants. G.M., which marketed the all-electric EV-1 with little success from 1996 to 1998, is already studying ways to introduce a small gasoline-electric hybrid vehicle, using its technical partnership with Toyota, Mr. Pearce acknowledged. While G.M. and Toyota officials refuse to elaborate, environmentalists say that the companies are working on a gasoline-electric car that would look like a sport utility vehicle and would probably be manufactured at their joint operation in Fremont, Calif.

But there are engineering limits to the fuel efficiency of gasoline engines, and automakers appear to be approaching those limits. So G.M., Ford and DaimlerChrysler have been working with the government on diesel-electric hybrids instead. Diesel engines can be up to 30 percent more efficient than gasoline engines. However, even though today's diesels are far cleaner and quieter than earlier versions, they may still run afoul of the new and unexpectedly tough state and federal air pollution regulations.

The auto industry's problems began a year ago, when the California Air Resources Board met to approve a staff proposal to require sport utility vehicles and other light trucks to meet the far more stringent air pollution standards for cars. One of the board members, who are political appointees, noted that the staff proposal did not change the rules on diesel-powered light trucks. Yet the board had voted the month before to classify diesel emissions as a toxic air contaminant. Automakers had been laying plans for years to build more sport utility vehicles with conventional diesel engines so as to meet Federal fuel economy rules.

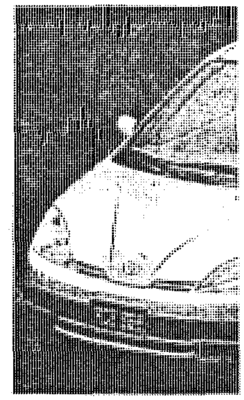
After less than half an hour of discussion, and with no staff analysis, the board amended the staff's proposal to eliminate the agency's longstanding separate regulations for diesel-powered family vehicles. Even though diesels offer better fuel economy and produce lower quantities of gases associated with global warming, they will be subject to the same strict standards as gasoline-powered cars, beginning with the 2004 model year. Effectively, that will mean new cars with diesel engines will be banned from California.

"Fuel economy is strictly a federal area; we don't deal with it, we don't have the mandate to deal with it," Richard Varenchik, a spokesman for the board, said. Prodded by a national lobbying effort by environmentalists against pollution by sport utility vehicles, New York and Massachusetts are now moving to adopt California's emissions rules, including the diesel provisions.

President Clinton gave final approval last week to strict new federal regulations on tailpipe emissions that will also take effect with the 2004 model year. The federal rules are slightly less stringent than California's standards; Gary Guzy, the general counsel of the Environmental Protection Agency, said that with further research, it should be possible to develop diesel engines clean enough to comply with the least stringent category.

But automakers will only be allowed to sell a limited number of vehicles in that category, which they already plan to use for large sport utility vehicles and pickup trucks. As a result, automakers will face a choice between selling high-mileage, diesel-electric hybrid cars or selling large, high-profit sport utility vehicles and pickups.

Automakers once hoped that the Republicans who control Congress would rescue them from their environmental predicament, but that hope is evaporating like a puddle of spilled gasoline. Stung by environmentalists' television advertisements in New Hampshire criticizing air pollution in Texas, Gov. George W. Bush, a leading candidate for the Republican presidential nomination, said in a debate in New Hampshire in early December that he favored the federal air quality rules that President Clinton was about to approve. Two weeks later, Mr. Bush asked the Texas Natural Resources Commission to consider adopting California's auto emissions rules.



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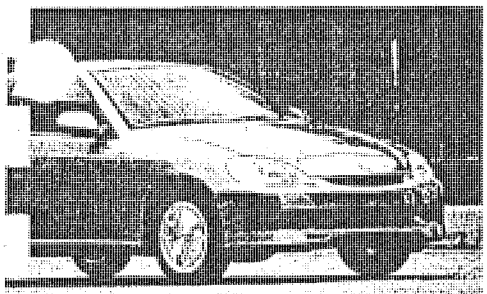
atch-Up in Race for a Hybrid Car



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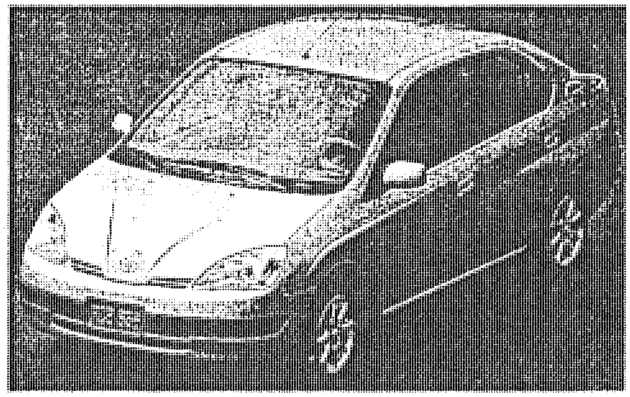

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Even if an unexpected technological breakthrough allows automakers to address the emissions problems of diesel engines, a bigger question looms: How many Americans will want very high-mileage cars? New automobile buyers these days rank fuel economy down with the quality of seat fabrics and interior carpeting, behind two dozen other considerations, according to recent surveys by Auto Pacific, a market research firm in Santa Ana, Calif.

Americans pay so little attention to gasoline these days because it is so cheap, even after a run-up in prices over the last year. The United States has the lowest gasoline taxes of any large industrialized country. In Europe and Japan, where high taxes push the price to $4 or $5 a gallon, small cars are much more popular, which is why their citizens are expected to buy large numbers of hybrids long before Americans do.

Hybrid cars also have a few nuisances that may irritate Americans spoiled by the power of gasoline-powered cars. For instance, most models — including the Precept, Insight and Prius — have fuel-efficient manual transmissions, which are becoming almost extinct in the American auto market.

The hybrids also have less power to spare for accessories. The Prodigy, an experimental, diesel-electric car that Ford also plans to display at the North American International Auto show early in January where the G.M. car will be introduced, has an air-conditioning system that shuts down whenever the car stops. The car's electric motor is not strong enough to run the air-conditioning by itself.

Rescuing the occupants of hybrid vehicles after crashes could also prove tricky. While the hybrids meet Federal safety standards when crashed into concrete barriers, their batteries and high-voltage cables pose special risks for rescuers who must cut into vehicles to save trapped motorists.

The auto industry and federal officials say that they plan to continue working on all these problems, and will hope for breakthroughs in their research.

The United States still needs to keep working on high-technology cars, Bill Richardson, the energy secretary, said, because "getting a highly fuel-efficient car that can meet the demands of U.S. consumers in the market will reduce pollution and enhance our energy security."

CBS Holders Back Merger

By Reuters

Shareholders of the CBS Corporation have voted overwhelmingly to approve the company's $37 billion merger with Viacom Inc. Viacom shareholders have also approved the deal. About 99 percent of CBS shareholders backed the deal. Viacom, which owns MTV, Paramount Pictures, half of the UPN broadcast network and television stations and entertainment properties, said it had received backing for the deal from holders of its class A shares. Upon completion, CBS shareholders will get 1.085 shares of nonvoting Viacom stock for each CBS share. The CBS vote was held on Wednesday.

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Auto makers unveil high-mileage hybrids

By Royal Ford, Globe Staff, 12/06/99

In what is the start of an evolving and potentially momentous change in America's automobile culture, car buyers this month have a mass-market option to purchase cleaner-burning, very high mileage, alternative automobiles.

Significantly, these vehicles - generically called "hybrids" - are not tied to range-limiting infrastructures, such as electric recharging stations or exotic refueling centers that have yet to be created. Instead, they rely on small gasoline engines aided by electric motors whose batteries are constantly being recharged as the vehicle is driven. They are refueled at gas stations just like regular automobiles.

The two-seater Honda Insight, in dealer showrooms on the West Coast this month and in the East in January, is just the first of many hybrids in the works. Toyota will begin selling the Prius, a four-person commuter car, in mid-2000. Several American manufacturers are using hybrid technology to improve gasoline mileage in larger sedans, SUVs, pickup trucks, and buses, believing that more significant fuel savings can be made through changes in the more popular larger vehicles.

But for hybrids to survive, manufacturers say, Americans will have to be convinced that the cars are not just a gimmick, that they are easily refueled, and that they behave much like the vehicles we drive today.

The Insight makes a convincing demonstration. The car moved easily in the flow of high-speed commuter lane traffic on Interstate 93 just outside Boston on a recent week-long test drive. When the digital speedometer read 75 miles per hour, a moving bar graph just below the speedometer indicated the car was getting 42 miles per gallon of gasoline.

With a move to the middle lane, a drop in speed to 67, and a gentle but steady pressure on the gas pedal to maintain that speed, the miles-per-gallon reading jumped to 82. A neon circle to the right of the speedometer showed that the batteries to run its electric motor were fully charged.

The car, with its 10.6-gallon gasoline tank just filled, could have continued from here into

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the heart of North Carolina before needing more gasoline. A typical small sedan might get 30 miles per gallon and on a 12-gallon tank would likely need refueling around Philadelphia.

The Insight may be first to hit the mass market, but it will not be alone for long.

John Wallace, the director of environmental vehicles at Ford Motor Co., recalled that during a recent visit to the International Auto Show in Tokyo, "You couldn't walk without tripping over a hybrid." Also on display, he noted, were limited-use electric vehicles and developmental vehicles, thought to be 10-20 years in the future, called "fuel cell" autos, whose hydrogen power source would replace gasoline.

Hybrids represent a significant moment in the development of automobiles, a time when technology, culture, politics, and business mesh. They drive very much like a standard automobile, are environmentally friendly, may render moot legislation mandating that a certain percentage of cars sold in a state be all-electric, and if enough Americans can be persuaded to buy them will not only save millions of dollars in gasoline expenses but also give auto dealers a hot new product.

With the hybrid, unlike the battery cars in the market, there is no need to plug into anything; and unlike natural gas-powered vehicles there's no need to find alternative combustion fuels at sparse pumps. Instead, drivers will pull up to the local gas station, just like always.

"They never have to plug it in. It gives them not only freedom from the plug, but also lots more freedom from the gas station," said Robert Bienenfeld, Honda's alternative fuel vehicle sales manager.

That is because of the way the hybrid's gasoline and electric motors work in concert.

With the Insight, the electric motor assists the gasoline engine during a start from stop, during rapid acceleration, or on long steep climbs. When less effort is required, its one-liter, three-cylinder engine runs on its own. Power for the electric motor comes from 144 D-cell-sized batteries stored in a pack at the rear of the car.

They are kept charged by "regenerative braking," in which the electric motor, when not assisting the gasoline engine, becomes a generator and captures the heat and friction created when brakes are applied or the motor holds itself back, as in decelerating or on long downslopes. The vehicle stores this captured power as electrical energy in the batteries.

It is a symbiotic circuit of power that, industry specialists said, can be used to turn already high-mileage cars into super high-mileage cars, or low-mileage cars, trucks, and SUVs into better mileage vehicles. Here, the industry splits into camps, with some manufacturers, notably the Japanese, starting small, and others, notably American, arguing that a 20 percent savings in gasoline in SUVs or pickup trucks would be of greater benefit than a 50 percent savings in autos that already run clean and get high mileage.

Honda's Insight offers a two-seat hatchback that uses lightweight materials - aluminum, alloys, special plastics - in body and engine. It can easily average 70 miles per gallon, has a top speed of just over 110 miles per hour and, except for a brief pause when the electric motor whirs when starting, behaves like any small gasoline-powered auto.

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At those prices, both companies will be losing money on each car sold. But, they are challenging that segment of American drivers who rail against gas-guzzlers, such as SUVs, to step up and buy an alternative. The cars cannot be profitable if only small numbers of them are sold, though Honda says that even if the Insight itself does not become a big seller, its technology will likely wind up in other Honda models within five years.

US companies, in comparison, are moving into hybrids not only from the other end of the auto spectrum, but also more cautiously. They are trying to sell better mileage to a customer base that does not seem to base purchases on fuel costs, and hoping for government help in their efforts.

DaimlerChrysler, for instance, has announced plans to build, by 2005, a hybrid version of its Durango SUV - providing Congress approves legislation that would give consumers as much as a $3,000 income tax write-off to subsidize the purchase of hybrid vehicles. The Durango hybrid would be powered by a V6 engine assisted by an electric motor. In tests, the V6 hybrid has actually proven stronger than the standard, 5.9-liter V8 Durango.

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Norman said that, over time, there will be "a significant improvement in gasoline mileage" based on several new forms of power. It will be good not only for consumers, he said, but for the environment and for the gasoline industry, where more drivers needing ever more fuel could put fierce production pressures on the industry and drive up the cost of fuel.

"It's misleading to think that one technology is going to solve all the problems," said Honda's Bienenfeld. "But right now, the gasoline infrastructure is perfect and the hybrid is certainly the first of these advanced technologies that is mass market ready."

This story ran on page A01 of the Boston Globe on 12/06/99.

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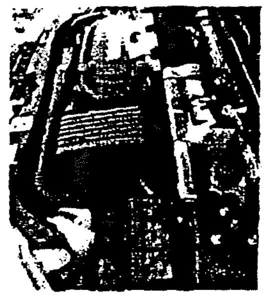
A battery compartment on the two-seat Honda Insight. The hybrid model is in showrooms on the West Coast.



Auto makers unveil high-mileage hybrids

By Royal Ford
GLOBE STAFF

In what is the start of an evolving and potentially momentous change in America's automobile culture, car buyers this month have a mass-market option to purchase cleaner-burning, very high mileage, alternative automobiles.

Significantly, these vehicles – generically called "hybrids" – are not tied to range-limiting infrastructures, such as electric recharging stations or exotic refueling centers that have yet to be created. Instead, they rely on small gasoline engines aided by electric motors whose batteries are constantly being recharged as the vehicle is

HYBRID, Page A10

Auto makers offering cleaner high-mileage hybrids

■ HYBRID
Continued from Page A1

driven. They are refueled at gas stations just like regular automobiles.

The two-seater Honda Insight, in dealer showrooms on the West Coast this month and in the East in January, is just the first of many hybrids in the works. Toyota will begin selling the Prius, a four-person commuter car, in mid-2000. Several American manufacturers are using hybrid technology to improve gasoline mileage in larger sedans, SUVs, pickup trucks, and buses, believing that more significant fuel savings can be made through changes in the more popular larger vehicles.

But for hybrids to survive, manufacturers say, Americans will have to be convinced that the cars are not just a gimmick, that they are easily refueled, and that they behave much like the vehicles we drive today.

The Insight makes a convincing demonstration. The car moved easily in the flow of high-speed commuter lane traffic on Interstate 93 just outside Boston on a recent week-long test drive. When the digital speedometer read 75 miles per hour, a moving bar graph just below the speedometer indicated the car was getting 42 miles per gallon of gasoline.

With a move to the middle lane, a drop in speed to 67, and a gentle but steady pressure on the gas pedal to maintain that speed, the miles-per-gallon reading jumped to 82. A neon circle to the right of the speedometer showed that the batteries to run its electric motor were fully charged.

The car, with its 10.6-gallon gasoline tank just filled, could have continued from here into the heart of North Carolina before needing more gasoline. A typical small sedan might get 30 miles per gallon and on a 12-gallon tank would likely need refueling around Philadelphia.

The Insight may be first to hit the mass market, but it will not be alone for long.

John Wallace, the director of environmental vehicles at Ford Motor Co., recalled that during a recent visit to the International Auto Show in Tokyo, "You couldn't walk without tripping over a hybrid." Also on display, he noted, were limited-use electric vehicles and developmental vehicles, thought to be 10-20 years in the future, called "fuel cell" autos, whose hydrogen power source would replace gasoline.

Hybrids represent a significant moment in the development of automobiles, a time when technology, culture, politics, and business mesh. They drive very much like a standard automobile, are environmentally friendly, may render moot legislation mandating that a certain percentage of cars sold in a state be all-electric, and if enough Americans can be persuaded to buy them will not only save millions of dollars in gasoline expenses but also give auto dealers a hot new product.

> 'It gives them not only freedom from the plug, but also lots more freedom from the gas station.'
>
> ROBERT BIENENFELD
> *Honda manager*

With the hybrid, unlike the battery cars in the market, there is no need to plug into anything; and unlike natural gas-powered vehicles there's no need to find alternative combustion fuels at sparse pumps. Instead, drivers will pull up to the local gas station, just like always.

"They never have to plug it in. It gives them not only freedom from the plug, but also lots more freedom from the gas station," said Robert Bienenfeld, Honda's alternative fuel vehicle sales manager.

That is because of the way the hybrid's gasoline and electric motors work in concert.

With the Insight, the electric motor assists the gasoline engine during a start from stop, during rapid acceleration, or on long steep climbs. When less effort is required, its one-liter, three-cylinder engine runs on its own. Power for the electric motor comes from 144 D-cell-sized batteries stored in a pack at the rear of the car.

They are kept charged by "regenerative braking," in which the electric motor, when not assisting the gasoline engine, becomes a generator and captures the heat and friction created when brakes are applied or the motor holds itself back, as in decelerating or on long downslopes. The vehicle stores this captured power as electrical energy in the batteries.

It is a symbiotic circuit of power that, industry specialists said, can be used to turn already high-mileage cars into super high-mileage cars, or low-mileage cars, trucks, and SUVs into better mileage vehicles. Here, the industry splits into camps, with some manufacturers, notably the Japanese, starting small, and others, notably American, arguing that a 20 percent savings in gasoline in SUVs or pickup trucks would be of greater benefit than a 50 percent savings in autos that already run clean and get high mileage.

Honda's Insight offers a two-seat hatchback that uses lightweight materials – aluminum, alloys, special plastics – in body and engine. It can easily average 70 miles per gallon, has a top speed of just over 110 miles per hour and, except for a brief pause when the electric motor whirs when starting, behaves like any small gasoline-powered auto.

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Continued from preceding page

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Passes semis

The Insight's impressive EPA numbers come not just from its engine design, but also from its aerodynamic construction. It is light-weight, using aluminum, alloys, and special plastics in both body and engine. The car is 47% lighter than conventional steel bodies of comparable size, including Honda's own Civic. The car's teardrop shape is impressively aerodynamic. Its coefficient drag (wind resistance vs forward motion) of 0 25 is at the top of any production automobile. Unlike its electric predecessors, it will overtake a semi on Route 128

A camel

"Fill'er up", "plug 'er in" are now anomalies.

It keeps going, and going... The Insight does not require recharge every 70 miles like most electric cars and it will travel 600-700 miles on a single tank of gas.

How it keeps going... The electric motor assists the engine when it is at its weakest, during acceleration and at low speeds. The gas engine runs alone at its most efficient state, cruising speed. Batteries for the electric motor are charged when the brakes are applied and the car slows down. This "regenerative braking" produces energy that is converted to electricity and stored

When it stops... The engine shuts down when the car is in neutral and the clutch is held down It starts when the car is put back into gear and restarts the engine. The electric motor doubles as a starter, and because of its size and configuration it is more powerful and less noisy than a conventional starter

Features

Driving like most small compacts the two-seater Insight comes with an array of features.

- Antilock brakes
- Electric power steering
- Power windows, locks and mirrors
- Dual air bags
- AM/FM stereo cassette
- Keyless entry and antitheft device
- Automatic air conditioning available

SOURCES: Honda The EPA New York Times, TIME, and Forbes

GLOBE STAFF GRAPHIC · JOAN McLAUGHLIN

MONDAY

Automotive News®

EVS-14 SYMPOSIUM & EXPOSITION DAILY

DECEMBER 15, 1997 ORLANDO

in brief

Costa Rica welcomes EVs

Costa Rican President Jose Maria Figueres wants to jump-start sales of electric vehicles in his country.

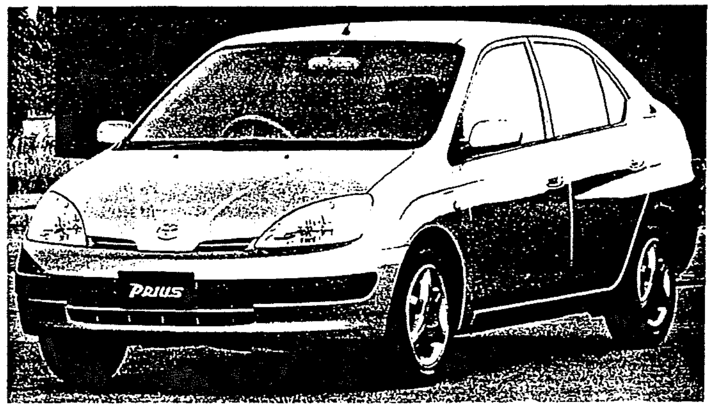
So Figueres has slashed the import duty on electric vehicles from 100 percent to 38 percent, has set up a $10 million line of credit for electric vehicle makers and buyers to draw upon for financing buyers, and is negotiating with the state-owned power company to cut the charge for electricity to make recharging cheaper.

Figueres talked about his efforts Friday, Dec. 12, after touring the 14th International Electric Vehicle Symposium and Exposition. He also touted an international forum on electric and alternative vehicles, scheduled for March 9-11 1998, in Costa Rica.

– Dale Jewett

Prius bound for U.S.

Toyota hybrid due here by 2000



Toyota began selling the Prius hybrid in Japan this month.

Eager to display its "green" credentials, Toyota Motor Corp plans to offer the Prius electric hybrid-powered sedan in the United States no later than 2000

Last week in a press briefing during the 14th International Electric Vehicle Symposium and Exposition, the automaker confirmed that the U.S market will get small numbers of the car which went on sale this month in Japan starting at $17,995

"We'll start small-volume, pilot marketing as early as possible, and before the end of the century," said Jane Beseda, manager of strategic planning for Toyota Motor Sales U.S A Inc She would not say how many Prius units would be available in the United States.

The most likely markets will be California and the Northeast, where environmental sentiment is relatively strong, Beseda said.

To make the Prius' more attractive to American motorists, Toyota will make some minor changes, such as beefing up its air conditioning unit

Coming on the heels of the Kyoto global-warming conference, a U S version of the Prius seems certain to spark interest Although the Big 3 are tinkering with hybrids, no other automaker is selling them commercially

The Prius carries an electric motor that can be powered by nickel-metal hydride batteries or a 1.5-liter gasoline engine

Depending on the need for acceleration, the car can run on the batteries only, the engine only, or both. Toyota claims the Prius gets about 66 mpg under urban driving conditions

The Prius will meet California's Low Emissions Vehicle standards, according to Toyota

Critics have claimed Toyota will lose up to $16,000 on the sale of each Prius Last week, Toyota executives declined to estimate the size of its subsidy, but acknowledged that it will lose money on each vehicle

Toyota says, however, that the subsidy will whet consumer demand, eventually raising sales volumes to profitable levels

– David Sedgwick

New batteries to boost range of Chrysler EPIC

Chrysler Corp is changing the batteries in its electric EPIC minivan to boost the vehicle's range

Chrysler hopes the change will spur interest in the vehicle

Next fall, Chrysler plans to install nickel-metal hydride batteries in the EPIC for the 1999 model year, giving it a daily range of 80 to 90 miles

The current version is powered by less-sophisticated lead acid batteries, which give it a 68-mile range

The new batteries will be heavily subsidized Chrysler declined to estimate the actual cost of the battery pack, but prototypes of nickel-metal hydride battery packs can cost tens of thousands of dollars apiece

The EPIC gets nickel-metal hydride power.

Chrysler will lease the EPIC in California and New York Chrysler will offer three-year lease options of $450 a month and no down payment, or a one-time $15,000 payment

Chrysler is upgrading the EPIC because the current version is not leasing well So far, Chrysler has leased 17 EPICs in California Under a three-year agreement with the California Air Resources Board, the company is supposed to lease 257 electric vehicles through 2000

"It's difficult to sell any vehicle that goes less than 100 miles and takes eight hours to recharge," Jim Cerano, Chrysler's EPIC program manager, told the press during the 14th International Electric Vehicle Symposium and Exposition

Chrysler will buy the batteries from Saft, a French supplier

Since Chrysler is switching to advanced batteries, California regulators will require the company to lease only 120 more electric vehicles through 2000

– David Sedgwick

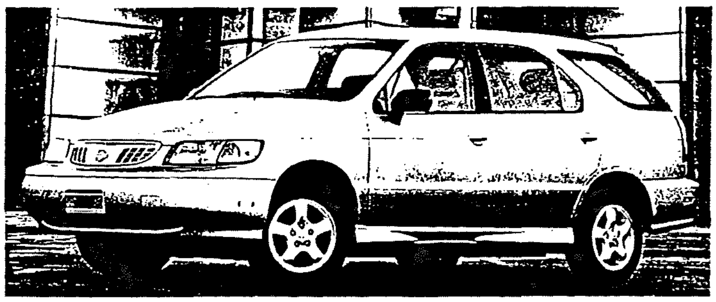
Nissan's Altra EV to join fleets in '98

Consumers will be able to lease Nissan's new Altra EV in a couple of years

But first the automaker will put about 125 of the electric-powered station wagons into service with fleet and utility customers Nissan will deliver an initial group of 30 Altras next March, and another 95-100 wagons in the 1999 model year, said John Schutz, director of regulatory affairs for Nissan Research and Development Inc

Schutz: Better batteries

The slow startup is related to the Altra EV's advanced, but expensive, lithium-ion batteries, Schutz said The batteries are still in the prototype stage, so they are being produced slowly



Nissan says it designed the Altra EV to suit American tastes.

Lease rates for the public have not been determined, Schutz said. Three-year leases for fleets are being negotiated on a case-by-case basis

Nissan used the 14th International Electric Vehicle Symposium and Exposition for the first public showing of the Altra EV in North America The vehicle is to be displayed at the Detroit and Los Angeles auto shows next month

The Altra EV was designed with American consumer tastes in mind, Schutz said The vehicle, along with a gasoline powered version dubbed the R'Nessa, were first shown at the Tokyo Motor Show in October But Nissan has no plans for importing the R'Nessa to the United States, Schutz said

The Altra EV has many of the same features as its competitors: dual airbags, regenerative braking, antilock brakes, electric power steering, and low rolling-resistance tires With a wheelbase of 110 2 inches and overall length of 191 7 inches, the Altra EV fits between the Maxima sedan and Quest minivan in size

The Altra EV's main difference is its battery pack – a lithium-ion unit developed with Sony Corp Nissan is the first major automaker to use lithium-ion batteries, now commonly used in cellular telephones and laptop computers

The lithium-ion batteries give the Altra EV a longer range – Nissan claims 80-100 real-world miles – and a long life Schutz said even though they are more expensive, the batteries' longer life makes them cost competitive vs other battery technologies

– *Dale Jewett*

Lessees teach Honda about market for EV Plus

In the last six months, Honda has put 79 EV Plus electric vehicles on the road in California. In that time, Honda has found out that

■Most users believe the 60- to 80-mile range from the car's nickel-metal hydride battery pack is adequate

■Owners like driving their vehicles as much as possible to get the most benefit from the lease, which costs $455 a month, and because of their desire to help the environment

■The experience has exposed some minor technology and distribution glitches In one case, an EV Plus was kept off the road while Honda found a replacement for one of its low rolling-resistance tires that had been damaged

Honda says most users are satisfied with the 60- to 80-mile range of the EV Plus.

Overall, Honda is happy with its EV Plus experience, said Bob Bienenfeld, manager of alternative fuel vehicles for Honda

So are its customers. For its presentation at the 14th International Electric Vehicle Symposium and Exposition Honda brought the Lucey family from Los Angeles, one of the first lessees of an EV Plus

Peter and Janet Lucey originally leased the EV Plus to be Janet's primary vehicle, but they now compare plans for each day and give the EV Plus to the driver who expects to do the most traveling, Janet Lucey said

Peter Lucey said the farthest he has driven the EV Plus on a single charge is 127 miles, which included four three-mile laps around the Rose Bowl parking lot

Customers are happy with the vehicle's range. Bienenfeld said "There has not been a clamor for public charging from our customers," he said If we had used lead acid batteries, I think there would be more demand for public charging "

Still, Honda and Ford Motor Co have agreed on a joint program to install public charging stations in the Los Angeles area

Bienenfeld said the EV Plus experience has taught him more about marketing to electric-vehicle buyers "The challenge is to keep them informed about what we're doing, and to target the advertising "

– *Dale Jewett*

Washington Post 3/17/99

The prototype of DaimlerChrysler's Necar 4 can travel 280 miles before refueling.

DAIMLERCHRYSLER PHOTO

Automakers Plan Fuel-Cell Cars

Some Vehicles to Run on Hydrogen-Oxygen Reaction

By WARREN BROWN
Washington Post Staff Writer

Two of the world's biggest car companies are planning to introduce a new line of non-polluting vehicles that ultimately could displace gasoline- and diesel-powered cars and trucks.

DaimlerChrysler AG, the world's fifth-largest automaker, and Ford Motor Co., the second-biggest, will unveil plans today to introduce hydrogen-fuel-cell cars, which will run on electricity generated by an electrochemical reaction between hydrogen and oxygen.

Both vehicles, DaimlerChrysler's Necar 4 and Ford's P2000, emit only water vapor as a byproduct of their chemically produced energy, meaning that they are cleaner than the cleanest of the gasoline-powered cars on the world's roads today.

DaimlerChrysler and Ford said they will begin producing fuel-cell cars for mass-market sales by 2004, aiming to beat other automakers to the market with "clean" cars. But auto executives admit these new vehicles must still address looming issues of price and weight before they become commercially viable.

For example, using current technology, a mass-produced fuel-cell car would cost $30,000 just for the fuel-cell hardware alone. That is 10 times the price of a current conventional gasoline engine, according to DaimlerChrysler's estimates.

Current fuel-cell components are also heavier and have more bulk than conventional engines, creating what auto designers call a "packaging problem"—that is, designing a vehicle to accommodate the components without sacrificing passenger and cargo space.

Toyota Motor Corp. and General Motors Corp. also have announced plans to have commercially viable fuel-cell vehicles ready within the next four years, while GM will be among those companies that are being honored today for breakthrough research in the development of fuel-cell technology.

Neal Lane, President Clinton's science adviser, will present the awards to 15 researchers at five companies on behalf of the administration's Partnership for a New Generation of Vehicles.

The partnership, composed of government and industry researchers, has a mission to develop cleaner, more fuel-efficient vehicles that can get triple the average fuel economy of today's models. If successful, that means the PNGV vehicles would get about 80 miles per gallon.

Neither DaimlerChrysler nor Ford is receiving PNGV medals today, but both companies are trying to position themselves as the most aggressive runner in the fuel-cell race.

It is an automotive competition long advocated by environmental groups, such as the Sierra Club. "This is what we've been waiting for," instead of the seemingly out-of-control battle for who can produce the biggest, most gas-guzzling truck or sport-utility vehicle, said Daniel Becker, director of the Sierra Club's global warming and energy programs.

Ironically, Becker said, the club just crowned Ford king of the gas-guzzler hill for developing and producing the Ford Excursion sport-utility model, the biggest such model to come to market to date.

"We can't wait to see more fuel-cells on the road. We are looking forward to a healthy competition to see who will make the cleanest car," Becker said.

DaimlerChrysler's Necar 4 prototype, which goes on display today, seems to have addressed at least the packaging issue. It is a subcompact, vanlike vehicle designed to seat five adults. It moves quickly from start to stop with modest engine noise. It can travel up to 280 miles before refueling, which is comparable to many of today's gasoline-powered cars.

D/C plans fuel-cell car price near $18,100

WIM OUDE WEERNINK
Staff Reporter

STUTTGART, Germany — DaimlerChrysler has set a price target for its first fuel-cell-powered car — even though its launch is five years away. The car is likely to be a version of the Mercedes-Benz A class.

Ferdinand Panik, head of DaimlerChrysler's fuel-cell group, believes consumers will refuse to pay premium prices for environmentally friendly cars.

"A fuel-cell car should have a competitive price tag," he said. "Therefore, we believe it should cost about the same as a similar-sized diesel model."

In Germany, a diesel-powered A class retails for about 35,000 German marks, or $18,084 at current exchange rates.

Panik said if DaimlerChrysler cannot meet its price target for the fuel-cell car, it will add luxury features such as air conditioning or an in-car refrigerator as standard. "These features benefit from the application of fuel-cell technology," which generates electricity, he said.

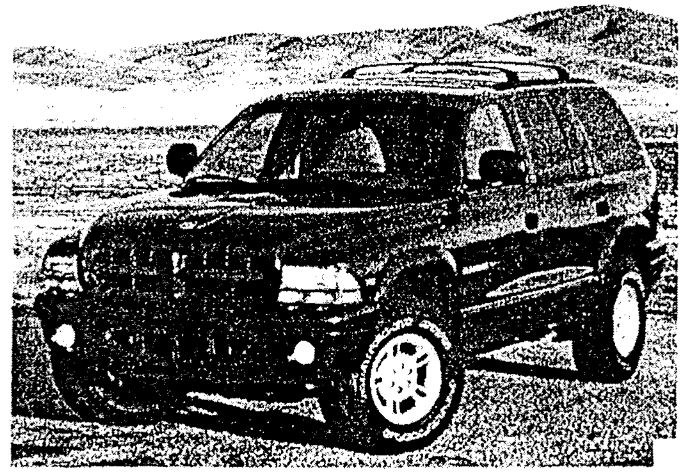
As part of the integration of the former Daimler-Benz and Chrysler activities, all fuel-cell research and development are now concentrated in Stuttgart.

"Because metropolitan areas benefit most from lower CO2 emissions, the use of fuel-cell technology (in a city car such as) the A class is most likely," he said. "The A class is also perfectly suited because of its double-floor platform concept."

DaimlerChrysler already has previewed an A class-based fuel-cell concept called the NECAR 4 (New Electric Car). It takes advantage of the deep "sandwich" cavity between the floor of the A class and the bottom of the car to house the fuel-cell equipment. On earlier versions, that equipment was big enough to fill the storage space of a van.

So far, DaimlerChrysler has not set sales targets for its fuel-cell car. Panik and Klaus-Dieter Voehringer, DaimlerChrysler's board member responsible for research and development, said the fuel-cell market will start with a few thousand units in 2004, but will increase to 50,000 or 100,000 a year by the end of that decade. AN

A whole lot of hybrid: A Dodge Durango using a hybrid engine makes a 70 per cent greater fuel saving than would be seen with a passenger car



Environment

DaimlerChrysler charts a third way for hybrids

Using green hybrid technology on a gas-guzzling SUV might seem perverse, but, as DaimlerChrysler has found, the benefits are actually magnified. Jesse Crosse looks at the Dodge Durango hybrid

The jury has been out on hybrid vehicles for some time now. The question has been whether they will follow the more complex mechanical path taken by Toyota with the Prius, or the arguably more simple approach favoured by Honda with the Insight.

The Prius uses a complex transmission and management system. The Honda uses an electric motor in line with the engine, an arrangement dubbed by the maker as Integrated Motor Assist. IMA seems a more likely approach to hybrid development in the future and is closely allied to the integrated starter-alternator technology under development by just about every major manufacturer.

However, DaimlerChrysler has come up with a radically different approach which it calls "through-the-road" (TTR) Hybrid. The idea is born of the desire to downsize SUV powertrains without reducing performance and while keeping cost to a minimum. The vehicle chosen for the experiment was a two-wheel-drive Dodge Durango sport utility vehicle (SUV) which has been converted to four-wheel-drive by the addition of an electric powertrain to the front wheels. The cost and weight of the 3-phase Siemens induction motor, which delivers 88.5hp and 190Nm torque, has been offset by discarding a conventional four wheel-drive transmission including transfer case, front drive shaft and one differential.

There are other gains too. The engine has been downsized from a 5.9-litre V8 to a 3.9-litre V6 and, as a result, many of the ancillaries have followed suit. There's a smaller catalytic converter, fan clutch, fan radiator and drive shaft. The fuel tank has been reduced by 20 per cent from 95 litres to 75 litres, resulting in a kerb weight close to that of the 5.9-litre four wheel-drive.

What, on the face of it, appears to be an oversimplified approach to a complex problem actually seems to work well. DaimlerChrysler claims that in an informal test against the bigger, conventionally-powered 4x4, the electric assist TTR Durango outpaced its rival under initial acceleration by over a length, having travelled just 15 metres. Th Durango is both quiet and powerful to drive, thanks to the fact that, usual, maximum torque is available from the electric motor from almo zero rpm

The action of the two mechanically separate powertrains is integrate electronically and the system is capable of recovering energy throug regenerative braking. The Durango was chosen on the basis that a 20 pe cent improvement in the fuel economy of a conventional Durango SUV, achieving only 15.2 litres per 100km fuel consumption, clearly has a greater impact on the environment than a similar improvement on a smaller, more efficient vehicle.

Fuel consumption of the TTR Durango is improved to 12.6 litres per 100km which equates to a 70 per cent greater saving being achieved than if the concept had been tried on a conventional US passenger car with a typical fuel consumption of 12.6 litres per 100km.

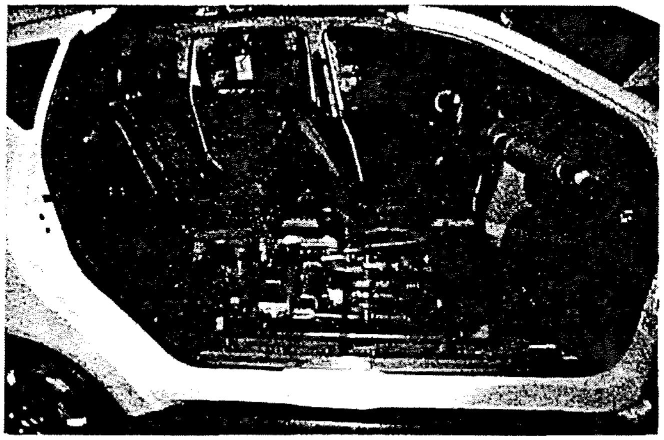
Lead acid batteries too heavy

Traction batteries are of the lead acid type and DaimlerChrysler admits they are too heavy and have a limited duty cycle. A new, lithium-ion battery under development by SAFT is receiving funding from the ABC (Advanced Battery Consortium), which is an initiative of the US Department of the Environment. The new batteries should be in full production by 2002 and will represent the cutting edge of battery technology.

Financially, the Durango TTR Hybrid could stack up. The car maker is under no illusion about the willingness of its customers to pay for environmental initiatives. With gasoline costing US$1.30 per US gallon, the TTR would only save 1.4 cents per mile given a 20 per cent improvement in fuel economy. Assuming the additional cost of the hybrid technology was US$4,000, it would therefore take 214,000 miles to recover the investment.

However, the TTR Hybrid scores on acceleration, especially at the lower speeds which matter in the US where drivers have no need of a top speed greater than 80 to 85mph. And drivers are prepared to pay more for performance, convenience and usability. Government aid may be also soon be forthcoming to support hybrid sales. The Energy-Efficient Alternative Propulsion Systems Bill before Congress at the moment allows for a tax incentive of US$3000 per vehicle. ■

Jesse Crosse is editor of FT Automotive Environment Analyst



Almost the real thing

DaimlerChrysler's scientists still have obstacles to overcome but commercial production in 2004 of its ground-breaking fuel cell vehicle, the Necar X, looks wholly feasible, says **Jesse Crosse**

This is not just another example of futuristic dreaming, no tiresome promise of what one day may happen, the kind of technical concept we have seen so often before. The Necar 4 is for real, it seats five people and carries them with ease. Hailed as the world's first driveable fuel cell vehicle, it is a watershed in automotive design.

Despite a planned production date of 2004, the level of finish makes it easy to believe the essential elements could be delivered sooner if DaimlerChrysler were put under any real pressure. Necar 4 has a range of 280 miles (450km), a top speed of 90mph (145 km/h) and fuel consumption is equivalent to a gasoline car achieving 3.2 l/100km or 88mpg. Electrical power actually comes from a stack of 400 fuel cells each producing between a half and one volt on demand, more than enough to power the 55kW, 250-volt drive train.

Inevitably, politics have played a part in the launch of this car. The last of six prototype DaimlerChrysler fuel cell vehicles in five years (including the Jeep Commander concept shown earlier this year) the Necar 4 runs on compressed hydrogen stored in a rear-mounted insulated tank at -230°C. Hydrogen is converted by the stack into electricity and water vapour, giving the car true zero emissions status, a crucial factor at the 17 March Washington launch attended by US Environmental Protection Agency administrator, Carol Browner, and covered by most of the US TV networks.

'Despite a planned production date of 2004, the level of finish makes it easy to believe the essential elements could be delivered sooner if DaimlerChrysler were put under any real pressure'

In reality, fuel cell cars driven by the general public will be powered by a liquid fuel, probably methanol. However, gasoline or a synthetic so-called designer fuel, using technologies being developed by companies such as Syntroleum and Fischer Tropsch, could also be used.

In those cases, the car will carry an on-board reformer to extract hydrogen from the fuel, a process which will also liberate CO_2, although 30 per cent less than a conventional car. Nevertheless, such versions will not have zero emissions status.

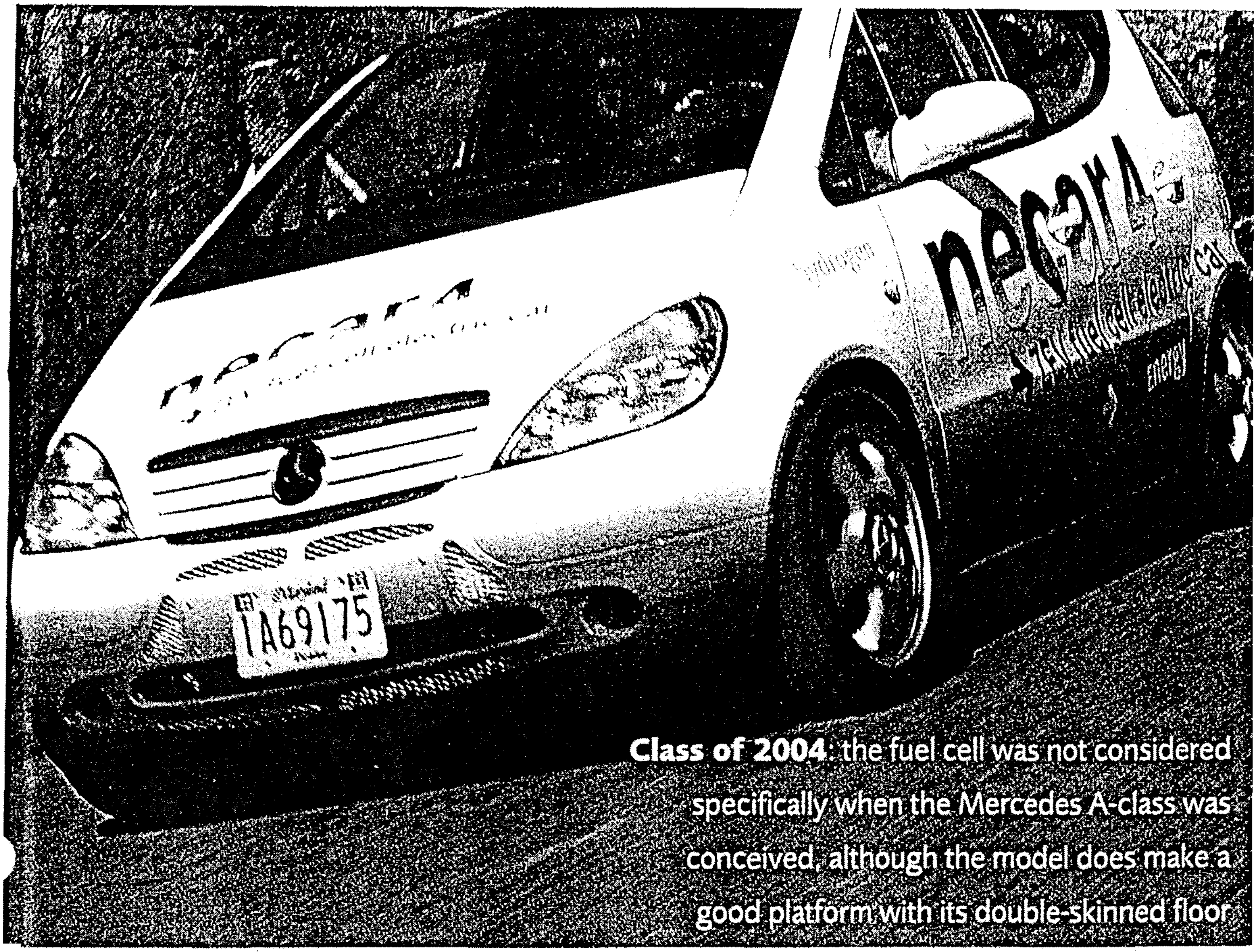
Starting-up difficulties

However, problems remain. Commercialising the reformer technology is described by Dr Ferdinand Panik, senior vice president, fuel cells, at DaimlerChrysler, as being "terribly difficult", particularly in relation to response and starting the high-temperature systems from cold.

He says: "Our methanol reformers take less than two minutes to start up, but to be commercially acceptable we must reduce that time to less than two seconds – and even that is too long." If the response time cannot be improved one option is to use a small hydrogen "buffer" tank.

The choice of fuel is crucial. For simplicity of manufacture, reformers are being tested to handle more than one type, but it is not expected that any technology will allow customers to switch fuel at will – the chemistry is too diverse. Although Panik says "we are remaining fuel neutral," methanol is a definite favourite; Panik also remarks that developing an infrastructure for its supply would "not be a problem".

Methanol is rich in hydrogen and low in hydrocarbon, there is a world glut of it, there are



Class of 2004: the fuel cell was not considered specifically when the Mercedes A-class was conceived, although the model does make a good platform with its double-skinned floor

All photos: Jesse Crosse

already 40 methanol filling stations in California, and the cost of converting others is not prohibitive.

A recent study by fuel cell pioneer Ballard Power Systems suggests the cost of converting 30 per cent of filling stations to handle methanol in the target launch states of California, Massachusetts, and New York would be \$400m (€380m). Designer fuel would cost \$200m, a figure Professor Klaus-Dieter Voehringer, member of the board responsible for research and development, dismisses as "insignificant, by my standards anyway".

Also favouring methanol is the fact that gasoline is more difficult to reform, the process producing hydrocarbons and requiring higher temperatures. Ordinary pump gasoline will not do either. A specially refined version will be needed for fuel cells, containing virtually no sulphur and no octanes or aromatics. Consequently, commercial systems are not expected until 2010 and naptha-based synthetic fuels are considered technically superior.

However, packaging is advanced and sources say a prototype DaimlerChrysler methanol reformer will fit into a space no bigger than 500mm square, although gasoline reformers would be larger. The entire system will fit beneath the floor of the compact A-class, as demonstrated in the Necar X final production concept shown at the launch. At 1,580kg compared with 1,170kg for the standard gasoline A-class, weight is still an issue, however, but the target weight of 1320kg will reduce the deficit from 400kg to 150kg.

In addition, confirms Panik, "we have 70kW stacks", a factor that makes the idea of fuel cell vehicles competing on an equal footing with combustion engined cars entirely believable.

Technology remains expensive

The other crucial factor is cost, as Panik explains: "Even for a mass-produced fuel cell vehicle [FCV], it would cost \$30,000 for the fuel cell hardware alone compared with today's internal combustion engine powertrain which costs \$3000."

But Firoz Rasul, president and CEO of fuel cell supplier Ballard Power Systems, a company whose actual worth is far higher than that suggested by the value of its stock or \$25m turnover, implies that the problem of manufacturing cost has already been largely overcome.

He says: "In order to reduce cost we have to ▶

The competition

General Motors showed its fuel cell technology to the press before Christmas and confirmed plans for a 2004 launch, although hardware is still apparently far less well packaged than that of DaimlerChrysler.

Ford is a partner with DaimlerChrysler, sharing Ballard fuel cells and services and Ecostar powertrains. Nissan has a methanol fuel cell prototype and has named an earlier launch date of 2003.

Renault is developing Megane Scenic-based alternative fuel prototypes but insists fuel cell vehicles are 10 years away.

Toyota's fuel cell programme, using its own stacks, is perhaps complicated by its commitment to hybrid technology. While Mitsubishi has said it will launch a FCV by 2003, a prototype is still awaited. ■

▶ figure out how to make the whole thing in a continuous process and the materials in a continuous fashion. At the same time we must retain the performance we get with current materials. We have identified the processes, and the materials are now in testing. Materials for 2004 are in place."

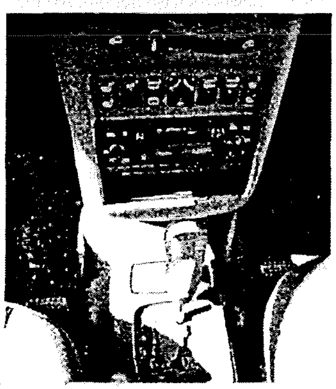
Ultimately, the aim is to produce a direct methanol fuel cell – one that also acts as a reformer and can be fed with methanol rather than hydrogen. Early tests show promise but Rasul is still cautious. He says: "We will not see the first commercially viable direct methanol fuel cell until at least 10 years after the first hydrogen fuel cell goes on sale." He also says: "We are in the front row in understanding how they work in the field rather than in the laboratory".

But it is the 2004 launch that is the focus of attention. Voehringer expects there to be "a two-pronged approach, with hydrogen for fleet use and methanol for the public".

Panik agrees: "Hydrogen has a chance in zero emissions states. We already have buses running and it is not so much of a problem as people think."

However, the chances of hydrogen becoming a global fuel in the near future are slim. Panik and Rasul think they are no closer to solving in-car storage problems, Rasul saying of one method: "We keep

"Our methanol reformers take less than two minutes to start up, but to be commercially acceptable we must reduce that time to less than two seconds – and even that is too long" *Ferdinand Panik*



Inside story:
'There is little discernible difference between this and a conventional automatic car, apart from the noise'

But how does it drive?

Despite a garish external colour scheme, the interior of the world's first driveable fuel cell car looks comfortingly ordinary, with austere charcoal grey upholstery and conventional seats.

Inside, the controls appear conventional too. A floor-mounted automatic gearbox selector lever allows the selection of park, drive and reverse and there are just two pedals, a throttle and brake.

The system starts on the ignition key like a conventional car and, after a short delay, sits humming quietly in standby mode.

Driving is simple. Squeezing the accelerator pedal brings forth a surprising and unusual guttural rasping noise as a compressor feeds air and hydrogen to the fuel cell stack.

The extra weight of the prototype lends a sturdy feeling to the handling and steering, but the electric motor delivers plenty of punch and the fuel cell car accelerates quite briskly up to 80km/h, speed only being curtailed by the narrow test route and a recurring thought that this car is probably the only one of its type in existence.

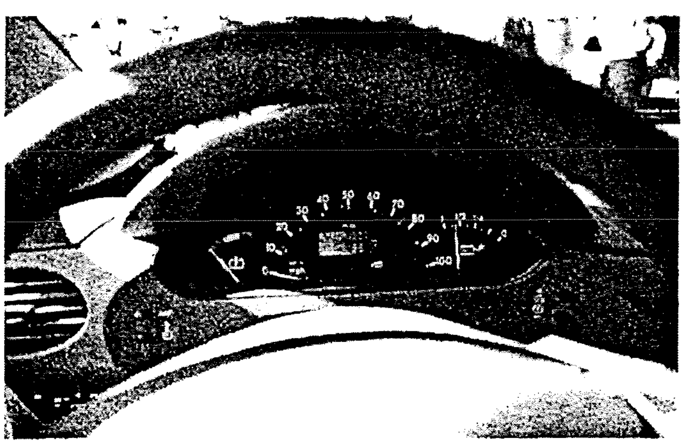
The experience is uncanny. Like all cars powered by electric motors, there is only a single, fixed gear ratio and no shifting of gears.

From silence at standstill, the motor whines quietly at speed but lift off the accelerator, and both the whining and the rasping noise cease.

Response to the throttle is instantaneous. Certainly, there is little discernible difference between this and a conventional automatic car and, in truth, it is hard to fault apart from the noise of the compressor. Instruments are standard A-class but with a fuel gauge reporting the quantity of hydrogen rather than gasoline.

There are two main differences between this and a conventional car. The first is the constant stream of torque delivered from standstill by the electric motor, while the second is the sound it makes.

Fuel cell cars will undoubtedly be extremely quiet by the time production is reached but, for now, the curious noise from the compressor under acceleration provides a glimpse, far into the future, of what the next generation of cars will be like. ■



hearing stories about nanofibres but they are still not viable," and Rasul saying of another, "We have tested metal hydrides but they are much too heavy for vehicles and too expensive."

But for now, the team is ebullient about its success, and clearly confident. When asked how the car would perform on the motorway, DaimlerChrysler co-chairman Juergen Schrempp answered quickly: "This car will behave as a typical Mercedes. It will be safe and it will be fast." Carol Browner sees the technology making it possible to "build a thriving economy for the 21st century" and DaimlerChrysler co-chairman Robert Eaton emphasised the importance of refining the new technology when he said: "Our challenge is to provide more earth friendly vehicles without penalty of cost or convenience."

Most important of all, perhaps, is that the massive problem of packaging fuel cells has been solved. What once filled an entire Mercedes van now fits beneath the floor of the A-class. As Schrempp also pointed out, "The A-class is not on the market in the US. The point of the A-class is to show it can be done in a small vehicle". It is a point that most people who have driven the Necar 4 readily accept. ■

Jesse Crosse is editor of FT Automotive Environment Analyst

"We can produce a few hundred vehicles for the 2004 launch. But from 2004 to 2010 the number of fuel cell vehicles must grow fast or else the [fuel] infrastructure will not grow" *Klaus-Dieter Voehringer*

Interview

Klaus-Dieter Voehringer

Spreading the technology

Professor Klaus-Dieter Voehringer is the member of the board of management responsible for research and development at DaimlerChrysler and will be involved in the resolution of many of the new problems arising before the final production fuel cell vehicle, dubbed Necar X, is launched in 2004

"The main disadvantage with this technology," says Professor Klaus-Dieter Voehringer, "is that it is quite different from conventional automotive technology. We can produce a few hundred vehicles for the 2004 launch – that is nothing. But from 2004 to 2010 the number of fuel cell vehicles must grow very fast, otherwise the [fuel] infrastructure will not grow.

"We have no idea of production volumes at this stage. We have to make that decision by 2002 so as to be ready for the 2004 launch.

"We are still deciding which parts we will manufacture in-house and which ones will be manufactured by suppliers.

"During the first year we will produce the car on different lines. Both types could one day be assembled on one production line. After all, fuel cells are just components, although different from those we are used to."

In terms of vehicle design and packaging the A-class is just a starting point. "The A-class went part of the way, but the fuel cell was not considered specifically when the A-class was conceived, although it does make a good platform with its double-skinned floor. We are still in the early stages but we are already deciding what a purpose-designed car will look like with this technology."

Once that time comes the cost of the new platforms and technologies will grow. DaimlerChrysler says it will have spent $1.4bn on its fuel cell programme by the time the Necar X goes into production, or the equivalent of an entire profit-making Chrysler model range.

It is an area ripe for new supplier businesses and venture capital funded companies too. Investment and complex partnerships, like that between DaimlerChrysler, Ford, Ballard Power Systems (and the subsidiary dbb set up by the partners) and Ecostar (electric powertrains) will be crucial to bearing the high costs which cannot be accounted for in existing budgets.

"We have increased funding for internal combustion engines, not reduced it. We cannot replace it. We need more money, otherwise we cannot go this way, and I think it is likely that smaller companies will be unable to afford this technology.

"dbb and Ecostar must be free to offer the technology to competitors. We know we have to spread the technology or it will not come. The same applies to the fuel infrastructure – nobody would do it just for DaimlerChrysler."

Most intriguing, perhaps, are the marketing aspects. Despite being the focus of attention, no decision has yet been made on whether to launch the conventional A-class in the US.

"The reason for bringing the A-class to the US market should not be decided by the fuel cell," he suggests. "If the A-class is not acceptable in the US, then we must consider another vehicle."

If that were the case, it is easy to speculate that the first American fuel cell vehicle could well carry a Chrysler, rather than a Mercedes badge. And that is something that would sit very comfortably indeed with the American public. ■

White Paper

Comparing the Emissions Reductions of the LEV II Program to the Tier 2 Program

October 2003

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I. Executive Summary

All new vehicles sold in the U.S. are subject to emissions standards set by either the federal government or the State of California. California is the only state with the authority to set its own vehicle standards; other states may adopt either the California or the federal standards.[1] In the 1990s, several Northeast states (specifically, Maine, Massachusetts, New York and Vermont) adopted the California Low Emission Vehicle (LEV) program in lieu of federal standards. Other Northeast states (Connecticut, New Hampshire, New Jersey and Rhode Island) currently participate in the federal National Low Emission Vehicle Program (NLEV) but now have the opportunity to switch to California's second-generation "LEV II" program. If they choose to remain with the federal program, cars sold in these states will be subject to federal Tier 2 emissions standards beginning in 2004 (with full implementation of the Tier 2 program in 2007), at which time NLEV will be replaced by the Tier 2 program.

Under the NLEV program, auto manufacturers agreed to provide voluntary, nationwide emissions reductions beyond the federal Tier 1 program on the condition that states not switch to California's standards before model year 2006. Because states must provide manufacturers with at least two years of lead time before implementing new emissions standards and because new model year vehicles typically enter the marketplace a year early, any Northeast states that are interested in adopting California's LEV II standards at the earliest possible date (i.e. in time to affect model year 2007 vehicles) must act before 2004.

NESCAUM commissioned this study to assist states in quantifying the emissions reductions of the California LEV II program compared to the federal Tier 2 program. As such, it is a follow-up to an earlier NESCAUM report which evaluated the emissions reductions of adopting the California LEV program in 1991. The analysis itself was conducted by Cambridge Systematics, Inc., an independent consulting firm that, for more than 20 years, has conducted projects associated with the implementation of transportation and air quality planning initiatives.

An important feature of the California program is that it includes an advanced technology vehicle component. Originally designed to mandate the introduction of battery electric "zero-emission vehicles" (ZEVs), California's ZEV requirement has since been changed to allow credit for a variety of advanced automobile technologies besides battery electric vehicles, including hybrid-electric vehicles, super low-emitting gasoline vehicles and hydrogen fuel cell vehicles.[2] Because the emissions benefits of LEV II

[1] The authority of other states to adopt California standards in lieu of federal standards was granted under Section 177 of the Clean Air Act Amendments of 1990.

[2] Advanced automobile technologies include vehicles with zero tailpipe and evaporative emissions (ZEVs), vehicles that have some electric drivetrain components (called advanced technology partial ZEVs or AT PZEVs), and conventional gasoline vehicles that meet certain emissions, durability, and warranty requirements (called partial ZEVs or PZEVs). Recent changes to the ZEV mandate greatly reduce the number of pure ZEVs required to meet the mandate

depend in part on how the ZEV mandate is complied with and since automobile manufacturers have significant flexibility in complying with the program, Cambridge Systematics evaluated four variations on that component of the California program.[3] The assumptions and methodologies used to conduct this analysis are detailed in Section V of this report; the different scenarios evaluated with respect to ZEV implementation are summarized in Table 5 on page 21.

Findings

Both the federal Tier 2 program and the California LEV II program will provide substantial further reductions in new vehicle exhaust emissions (on the order of 90 percent or more) over the next two decades. *However, the analysis conducted by Cambridge Systematics for NESCAUM finds that California's standards provide additional emissions reduction benefits over and above what the federal program is expected to achieve.* Specifically, the analysis finds additional reductions in light duty vehicle hydrocarbon (HC) emissions of 4 percent in 2010 and 16 percent in 2020 under the LEV II program compared to the federal Tier 2 program. Moreover, pollution benefits are particularly significant with respect to those HC emissions that are also considered toxic (e.g., benzene, formaldehyde and 1,3-butadiene). Specifically, additional reductions in toxic vehicle emissions under LEV II are estimated at approximately 25 percent in 2020, compared to the federal program. Finally, the analysis also finds that LEV II yields modest carbon dioxide reduction benefits (on the order of 3 percent in 2020) compared to Tier 2, primarily as a result of the advanced technology vehicle component of the California program.

The emission reduction benefits calculated in this analysis are summarized in the table below. Note that while absolute daily emissions reductions were calculated for three of the four Northeast states that have already adopted LEV II (Massachusetts, New York and Vermont[4]), similar benefits – in percentage reduction terms – would be expected for any other state choosing to adopt this program in lieu of federal standards.[5]

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[3] The analysis evaluated emissions from the fleet of light duty vehicles only, and not the two heavier classes of passenger cars that include heavier SUVs, pickup trucks, and minivans (LDT3 and 4). All four scenarios evaluated in this analysis included a minimum of 2 percent all-electric vehicles. California has revised its ZEV program since the analysis was conducted to largely eliminate the all-electric component. The impact of this change on the emissions results would however be minimal given that larger numbers of AT PZEVs will be used to replace the all-electric vehicles. An analysis prepared by California Air Resources Board staff and presented to the Air Resources Board in April concluded that "even though ZEVs are cleaner on a per vehicle basis, under our credit ratios over the long term one ZEV must be replaced by about six AT PZEVs. Therefore the greater numbers of AT PZEVs that are needed to replace ZEVs [as a result of the changes to the ZEV mandate] results in an air quality benefit. This analysis takes into account the change in implementation date for the ZEV mandate from 2003 to 2005."

[4] Maine, the fourth LEV state in the Northeast, was not included in the emissions analysis because Maine has chosen not to implement the ZEV component of the California program at this time. Since this feature is the source of much of the variation in emissions results between LEV II and Tier 2, emissions reduction benefits were not estimated for Maine.

[5] Note that the combined vehicle fleets of existing LEV II States – MA, ME, NY and VT – total approximately 16 million registered vehicles - approximately 62 percent of the Northeast light duty vehicle fleet.

Table ES-1: Annual Emissions Benefits of the LEV II Program in 2020

State	HC reduced (tons)	% HC Reduction Over Tier 2	Toxics[6] reduced (tons)	% Toxics Reduction Over Tier 2	CO_2 reduced (tons)	% CO_2 reduced
NY	10,020	15%	502	25% for each toxin	2,500,000	2.25%
MA	3,300	17%	185	25% for each toxin	900,000	2.25%
VT	510	14%	29	19% for each toxin	120,000	2.25%
Total	**13,830**	**Average Reduction 15.3%**	**716**	**Average Reduction 23%**	**3,520,000**	**Average Reduction 2.25%**

It is important to note, in connection with the findings summarized above, that calculated emissions benefits depend to a critical extent on assumptions made in the course of the analysis. The U.S. Environmental Protection Agency (EPA) has conducted its own comparative analysis of the California and federal programs and has reached different conclusions on different occasions. In a December 2001 draft guidance document, EPA recommended that states use the MOBILE6 model to compare LEV II and Tier 2 emissions. The approach EPA recommended at that time predicts LEV II will provide additional HC emissions reductions on the order of 21 percent compared to federal Tier 2. However, the approach recommended in a subsequent EPA guidance document – issued in June 2002 – predicts a substantially smaller HC benefit (on the order of 5 percent).[7] The latter result appears to have been driven largely by that fact that EPA assumed that vehicles that comply with the ZEV mandate will meet the same evaporative emissions standards as regular LEV II vehicles, even though California's evaporative standards are more stringent for ZEV-compliant vehicles. Further differences between EPA's most recent results and those found in this study arise from different assumptions about the compliance strategies used by manufacturers under the Tier 2 program. Specifically, the EPA June 2002 guidance assumed over-compliance with the emissions standards in lighter vehicles to make up for sales of heavier, more polluting vehicles. Based on NESCAUM's discussions with industry representatives, NESCAUM did not make that assumption for purposes of this analysis.[8] As a result, our findings are closer to those predicted in the earlier EPA assessment. It is important to

[6] Toxics include benzene, 1,3 butadiene, formaldehyde and acetaldehyde.

[7] EPA "Modeling Alternative NLEV Implementation and Adoption of California Standards in MOBILE6 Draft 12/21/01," and "Modeling Alternative NLEV Implementation and Adoption of California Standards in MOBILE6" June 5, 2002.

[8] Industry representatives described a compliance strategy whereby manufacturers will group vehicles around the Tier 2 bin 5 standards, rather than distributing vehicles broadly among the 8 bins. Targeting bin 5 will allow manufacturers to avoid mid-year corrections in vehicle sales to ensure that the fleet average emissions standards are met.

note that NESCAUM assumed that Tier 2 vehicles will meet regular LEV II vehicle evaporative emission standards, even though the LEV II evaporative emission standards are more stringent than the federal standards. The reason NESCAUM assumed this "over compliance" with the evaporative emission standards is that manufacturers have said they will manufacture cars in all 50 states which meet the LEV II evaporative emission standards. Thus, the NESCAUM study could underestimate the emissions reductions achieved in states that adopt the LEV II program - if manufacturers do not comply with this voluntary approach.

Conclusions

The LEV II program provides significant toxic and CO_2 emission reductions over the Tier 2 program. Unlike the federal program which will remain the same for at least a decade (as is required by the Clean Air Act) the California program will probably continue to become more stringent. Thus emissions differences between the California and federal programs will likely become greater as California adopts more stringent phases of the LEV program. In particular, risks associated with exposure to toxics such as benzene, formaldehyde, and 1,3-butadiene will be significantly reduced by adoption of the California LEV II program.

II. Introduction

All new vehicles sold in the U.S. are subject to emissions standards set by either the federal government or the State of California. California is the only state with the authority to set its own vehicle standards; other states may adopt either the California or the federal standards.[9] In the 1990s, several Northeast states (specifically, Maine, Massachusetts, New York and Vermont) adopted the California Low Emission Vehicle (LEV) program in lieu of federal standards. Other Northeast states (Connecticut, New Hampshire, New Jersey and Rhode Island) currently participate in the federal National Low Emission Vehicle Program (NLEV) but now have the opportunity to switch to California's second-generation "LEV II" program. If they choose to remain with the federal program, cars sold in these states will be subject to federal Tier 2 emissions standards beginning in 2004 (with full implementation of the Tier 2 program in 2007), at which time NLEV will be replaced by the Tier 2 program.

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manufacturers have significant flexibility in complying with the program, Cambridge Systematics evaluated four variations on that component of the California program.[11] The assumptions and methodologies used to conduct this analysis are detailed in Section V of this report; the different scenarios evaluated with respect to ZEV implementation are summarized in Table 5 on page 15.

III. Findings

Both the federal Tier 2 program and the California LEV II program will provide substantial further reductions in new vehicle exhaust emissions (on the order of 90 percent or more) over the next two decades. *However, the analysis conducted by Cambridge Systematics for NESCAUM finds that California's standards provide additional emissions reduction benefits over and above what the federal program is expected to achieve.* Specifically, the analysis finds additional reductions in light duty vehicle hydrocarbon (HC) emissions of 4 percent in 2010 and 16 percent in 2020 under the LEV II program compared to the federal Tier 2 program. Moreover, pollution benefits are particularly significant with respect to those HC emissions that are also considered toxic (e.g., benzene, formaldehyde and 1,3-butadiene). Specifically, additional reductions in toxic vehicle emissions under LEV II are estimated at approximately 25 percent in 2020, compared to the federal program. Finally, the analysis also finds that LEV II yields modest carbon dioxide reduction benefits (on the order of 3 percent in 2020) compared to Tier 2, primarily as a result of the advanced technology vehicle component of the California program.

The emission reduction benefits calculated in this analysis are summarized in the table below. Note that while absolute daily emissions reductions were calculated for three of the four Northeast states that have already adopted LEV II (Massachusetts, New York and Vermont[12]), similar benefits – in percentage reduction terms – would be expected for any other state choosing to adopt this program in lieu of federal standards.[13]

[11] The analysis evaluated emissions from the fleet of light duty vehicles only, and not the two heavier classes of passenger cars that include heavier SUVs, pickup trucks, and minivans (LDT3 and 4). All four scenarios evaluated in this analysis included a minimum of 2 percent all-electric vehicles. California has revised its ZEV program since the analysis was conducted to largely eliminate the all-electric component. The impact of this change on the emissions results would however be minimal given that larger numbers of AT PZEVs will be used to replace the all-electric vehicles. An analysis prepared by California Air Resources Board staff and presented to the Air Resources Board in April concluded that "even though ZEVs are cleaner on a per vehicle basis, under our credit ratios over the long term one ZEV must be replaced by about six AT PZEVs. Therefore the greater numbers of AT PZEVs that are needed to replace ZEVs [as a result of the changes to the ZEV mandate] results in an air quality benefit. This analysis takes into account the change in implementation date for the ZEV mandate from 2003 to 2005."

[12] Maine, the fourth LEV state in the Northeast, was not included in the emissions analysis because Maine has chosen not to implement the ZEV component of the California program at this time. Since this feature is the source of much of the variation in emissions results between LEV II and Tier 2, emissions reduction benefits were not estimated for Maine.

[13] Note that the combined vehicle fleets of existing LEV II States – MA, ME, NY and VT – total approximately 16 million registered vehicles - approximately 62 percent of the Northeast light duty vehicle fleet.

Table 1: Annual Emissions Benefits of the LEV II Program in 2020

State	HC reduced (tons)	% HC Reduction Over Tier 2	Toxics[14] reduced (tons)	% Toxics Reduction Over Tier 2	CO_2 reduced (tons)	% CO_2 reduced
NY	10,020	15%	502	25% for each toxin	2,500,000	2.25%
MA	3,300	17%	185	25% for each toxin	900,000	2.25%
VT	510	14%	29	19% for each toxin	120,000	2.25%
Total	**13,830**	**Average Reduction 15.3%**	**716**	**Average Reduction 23%**	**3,520,000**	**Average Reduction 2.25%**

It is important to note, in connection with the findings summarized above, that calculated emissions benefits depend to a critical extent on assumptions made in the course of the analysis. The U.S. Environmental Protection Agency (EPA) has conducted its own comparative analysis of the California and federal programs and has reached different conclusions on different occasions. In a December 2001 draft guidance document, EPA recommended that states use the MOBILE6 model to compare LEV II and Tier 2 emissions. The approach EPA recommended at that time predicts LEV II will provide additional HC emissions reductions on the order of 21 percent compared to federal Tier 2. However, the approach recommended in a subsequent EPA guidance document – issued in June 2002 – predicts a substantially smaller HC benefit (on the order of 5 percent).[15] The latter result appears to have been driven largely by that fact that EPA assumed that vehicles that comply with the ZEV mandate will meet the same evaporative emissions standards as regular LEV II vehicles, even though California's evaporative standards are more stringent for ZEV-compliant vehicles. Further differences between EPA's most recent results and those found in this study arise from different assumptions about the compliance strategies used by manufacturers under the Tier 2 program. Specifically, the EPA June 2002 guidance assumed over-compliance with the emissions standards in lighter vehicles to make up for sales of heavier, more polluting vehicles. Based on NESCAUM's discussions with industry representatives, NESCAUM did not make that assumption for purposes of this analysis.[16] As a result, our findings are closer to those predicted in the earlier EPA assessment. It is important to

[14] Toxics include benzene, 1,3 butadiene, formaldehyde and acetaldehyde.

[15] EPA "Modeling Alternative NLEV Implementation and Adoption of California Standards in MOBILE6 Draft 12/21/01," and "Modeling Alternative NLEV Implementation and Adoption of California Standards in MOBILE6" June 5, 2002.

[16] Industry representatives described a compliance strategy whereby manufacturers will group vehicles around the Tier 2 bin 5 standards, rather than distributing vehicles broadly among the 8 bins. Targeting bin 5 will allow manufacturers to avoid mid-year corrections in vehicle sales to ensure that the fleet average emissions standards are met.

note that NESCAUM assumed that Tier 2 vehicles will meet regular LEV II vehicle evaporative emission standards, even though the LEV II evaporative emission standards are more stringent than the federal standards. The reason NESCAUM assumed this "over compliance" with the evaporative emission standards is that manufacturers have said they will manufacture cars in all 50 states which meet the LEV II evaporative emission standards. Thus, the NESCAUM study could underestimate the emissions reductions achieved in states that adopt the LEV II program - if manufacturers do not comply with this voluntary approach.

The results of this analysis clearly show that the LEV II program provides significant emissions reductions over and beyond what the federal Tier 2 program provides for HC, toxics, and for CO_2.

IV. Discussion

The additional emissions benefits associated with LEV II and summarized in the previous section stem from two chief differences between the California and federal programs. First, the ZEV mandate described in Section I results in the introduction of vehicles with even lower emissions than those required of new conventional gasoline vehicles under either program. (While California has introduced additional flexibility to this aspect of its program, any gasoline powered vehicles used to satisfy the mandate will have to meet more demanding tailpipe and evaporative standards, as well as stringent durability requirements.)[17] Second, California's LEV II standards for evaporative and tailpipe HC emissions are more stringent than those of the federal Tier 2 program.[18]

Overall, approximately 30 percent of the additional hydrocarbon benefit estimated for the California LEV program is a consequence of the ZEV mandate (with the remaining 70 percent coming from more stringent evaporative and tailpipe standards); the ZEV mandate also accounts – as previously noted – for nearly all of the carbon dioxide benefit.

The results of this analysis indicate that Northeast States would derive air quality and public health benefits from adopting the California program in at least three areas:

- reducing ambient levels of priority airborne toxic pollutants
- attaining health-based air quality standards for ozone and fine particles
- meeting state and regional climate change objectives

[17] Specifically, eligibility for ZEV credit is tied to California's Super Ultra Low Emission Vehicle (SULEV) certification (tailpipe emissions as low as 0.01 g/mile NMOG), as well as near-zero evaporative emissions and a 150,000 mile durability requirement.

[18] Because of differences in the way each program structures its compliance requirements, it is difficult to make a straightforward comparison of the stringency of the LEV II standards compared to the Tier 2 standards. For example California requires manufacturers to comply with a fleet average for non-methane organic gas (NMOG) but not NOx and EPA requires manufacturers to comply with a fleet average for NOx but not hydrocarbons. In spite of these differences it is possible to assess relative program benefits using certain assumptions which, according to this analysis, suggest that LEV II provides additional emissions benefits over Tier 2.

Additional context for each of these issues is provided below. First, however, it is worth noting a final, important difference between the California and federal programs. That is, that California has historically revised its standards more frequently than the federal government. The result has often been more stringent standards in California for a period of some years before the federal standards "catch up." True to form, California air regulators are already beginning to discuss the possible parameters of "LEV III" successor standards to the LEV II requirements, while EPA has no plans at present for another round of federal standards. In short, states that adopt LEV II are likely to benefit from the additional reduction benefits associated with a tightening of California's requirements in coming years, whereas states in the federal program are unlikely to see further reductions from any changes to the Tier 2 standards for at least another decade or possibly longer.

A. Air Toxics

Although airborne toxins have not been the focus of most past regulatory efforts related to motor vehicle emissions, these pollutants represent an important health concern in the Northeast states and, according to our analysis, account for perhaps the most significant air quality and public health benefits of the California LEV II program compared to the federal Tier 2 program. In general, mobile sources (including both highway and nonroad engines) have been estimated to account for 75-90 percent of the total emissions inventory for four important air toxins (benzene, formaldehyde, 1,3-butadiene and acetaldehyde) in the Northeast.[19] Of these compounds, benzene has been classified by EPA as a "known" human carcinogen,[20] while formaldehyde and 1,3-butadiene are classified as "probable" carcinogens.

Recent studies indicate that current levels of these toxins in ambient air are a concern in many areas of the Northeast. For example, data from EPA's National Air Toxics Assessment (NATA) indicate that of the ten U.S. counties where modeling predicted the greatest added cancer risk from air toxics, 8 were in the Northeast.[21] This finding is buttressed by current state monitoring data that show ambient levels of air toxics exceeding state health benchmarks in every county of the Northeast.

Toxic air pollution should decline in the future as a result of several new federal mobile source emissions control programs, including not only the Tier 2 program, but EPA's recently issued highway diesel rule and new federal standards for nonroad gasoline engines, among other regulations.[22] Nevertheless, toxics are likely to remain a

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[19] http://www.epa.gov/ttn/atw/nata/

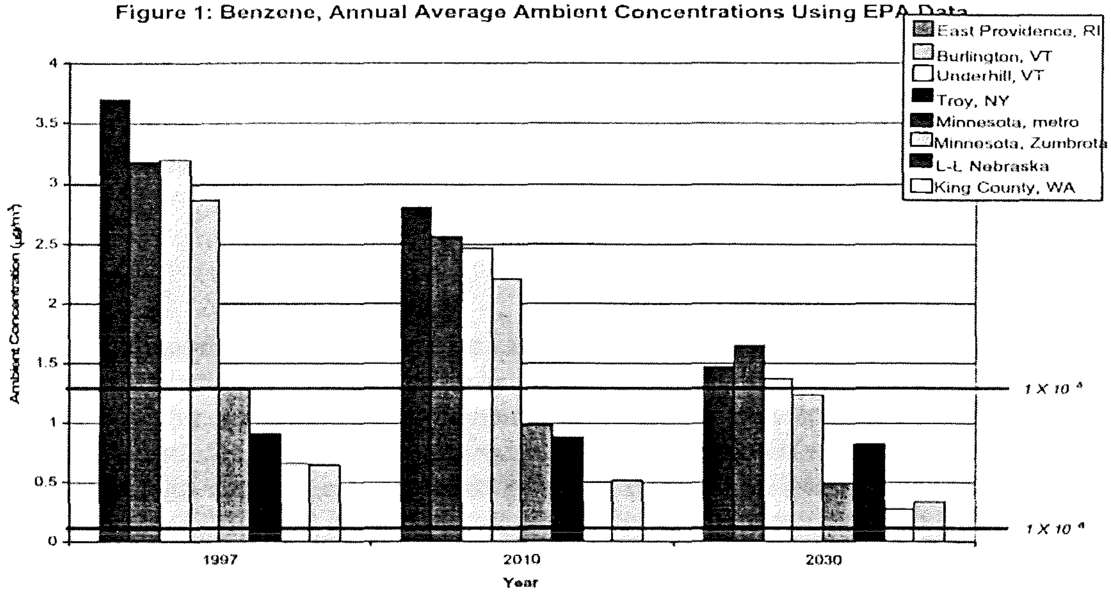
[20] Carcinogens are agents that cause cancer. EPA's classification of formaldehyde and 1,3 butadiene as "probable" carcinogens is based on epidemiological data and animal studies.

[21] In fact, the NATA study found that ambient levels of air toxics are likely to exceed the commonly used 1-in-100,000 added cancer risk threshold in all major American cities.

[22] "Control of Emissions of Air Pollution From Nonroad Diesel Engines and Fuel; Proposed Rule" May 23, 2003, 68 FR 28328, "Control of Emissions of Air Pollution from 2004 and Later Model Year Heavy-Duty Highway Engines and Vehicles; Revision of Light-Duty On-Board Diagnostics Requirements," October 6, 2000, 65 FR 59896, "Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur

significant concern for the foreseeable future. A recent NESCAUM analysis, for example, concluded that even taking into account new regulatory programs, ambient air toxics levels are likely to remain above the 1-in-100,000 cancer risk threshold in most U.S. urban areas and above the 1-in-1,000,000 risk threshold in all parts of the Northeast (rural and urban) through 2030. These results, in terms of predicted future benzene levels at sites in the Northeast and elsewhere, are graphically illustrated in Figure 1.

Figure 1: Benzene, Annual Average Ambient Concentrations Using EPA Data



In sum, given current and predicted levels of ambient air toxics – and given that light-duty vehicles represent an important part of the overall toxics inventory – the additional 25 percent reduction achieved by the California LEV program with respect to these pollutants is significant and is probably among the more compelling arguments for adopting LEV II in lieu of the federal Tier 2 program.

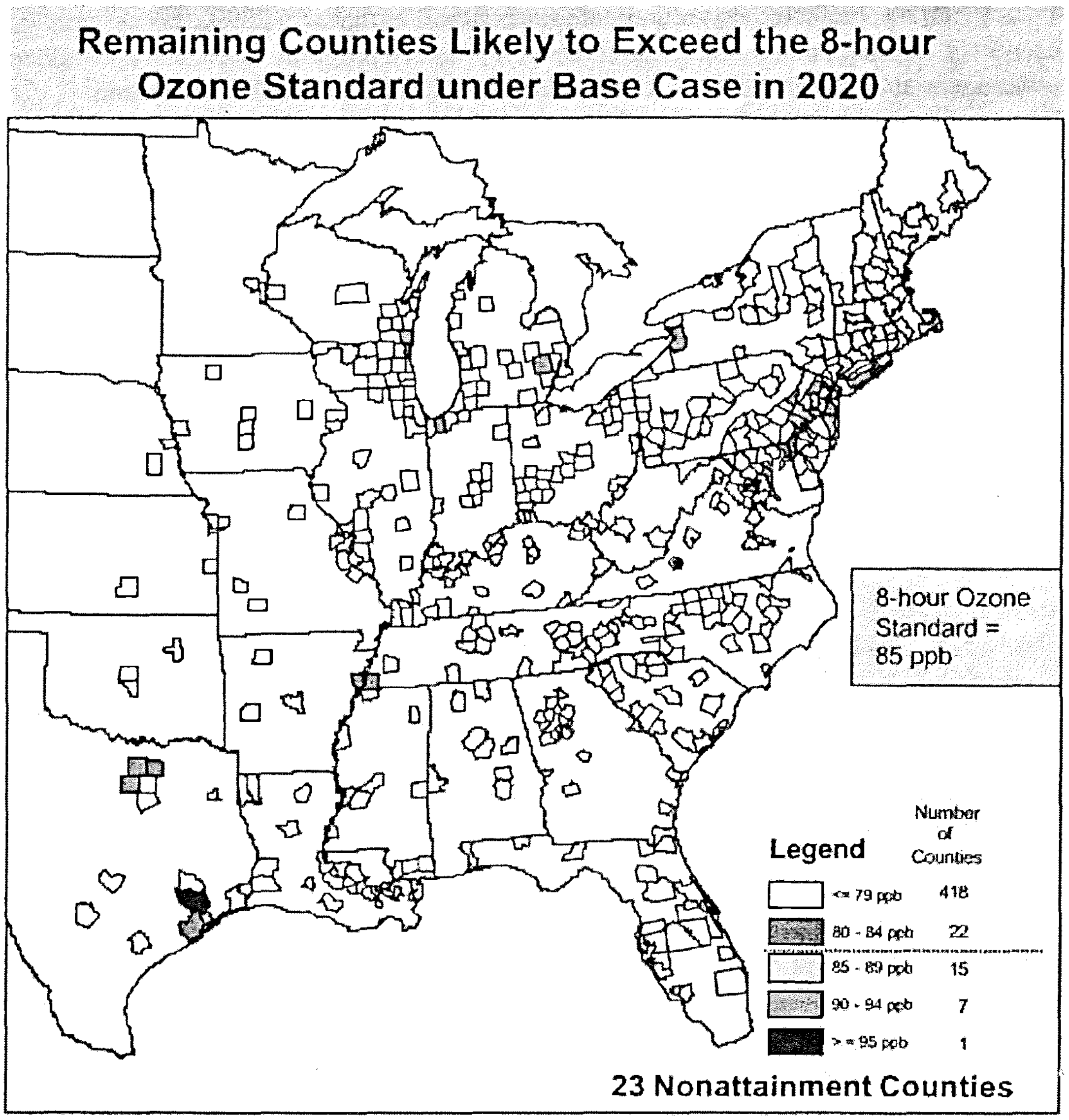
B. Ozone and Fine Particle Pollution

Attainment of health-based National Ambient Air Quality Standards (NAAQS) for ozone and fine particle pollution is likely to present significant policy challenges for Northeast states in the next decade and beyond. With the exception of Vermont, all of the states in the region have areas that violate the NAAQS for ozone. In addition, non-attainment problems are likely to become more widespread and difficult to rectify under

Control Requirements" January 18, 2001, 66 FR 5135, "Control of Emissions From Nonroad Large Spark-Ignition Engines, and Recreational Engines (Marine and Land-Based)" November 8, 2002, 67 FR 68241, "Phase 2 Emission Standards for New Nonroad Spark-Ignition Handheld Engines at or Below 19 Kilowatts and Minor Amendments to Emission Requirements Applicable to Small Spark-Ignition Engines and Marine Spark Ignition Engines," April 25, 2000, 65 FR 24268, "Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters Per Cylinder," February 28, 2003, 68 FR 9745, "Emissions Standards for Locomotives and Locomotive Engines; Final Rule," April 16, 1998, 63 FR 18978.

the new and more stringent ozone and fine particle NAAQS introduced by EPA in 1997. Figure 2 shows predicted non-attainment areas in the Northeast in 2020, taking into account all existing and currently anticipated regulatory programs. The map shows that non-attainment of the new 8-hour ozone standard is likely to remain widespread throughout the region. At the same time, non-attainment of the new fine particle ($PM_{2.5}$) standard is expected to be common in many urban areas.

Figure 2: 8-Hour Ozone nonattainment areas in 2020



Ozone attainment status in 2020 base case:

- **Existing programs (primarily the NOx SIP Call and vehicle rules, including the proposed non-road rule) will bring 245 eastern counties (home to approximately 65 million people) into attainment with the 8-hour ozone standard (compared to current conditions).**

Source: EPA

Both ozone and fine particle pollution are associated with serious health impacts. In the case of ozone, documented health risks include decreased lung function and increased respiratory problems, and – with repeated exposure – long-term and potentially irreversible lung damage. Meanwhile, large-scale epidemiological studies of the health risks associated with fine particle pollution have produced convincing evidence for a host of adverse effects, including premature mortality, aggravation of respiratory and cardiovascular disease and increased incidence of asthma attacks, chronic bronchitis and hospital visits. The substantial contribution of motor vehicles to ozone pollution is well established. Automobiles and other mobile sources emit hydrocarbons and nitrogen oxides (NOx), the two primary precursor pollutants that – when mixed in the atmosphere in the presence of sunlight – combine to form ozone. In fact, light-duty vehicles account for approximately one-third of all ozone precursor (NOx and HC) emissions in the Northeast. In the case of fine particles – which have emerged as a focus of air quality regulation and public health concern only in the last decade or so – the relative contribution of different source categories to ambient concentrations is less well understood. However, it is clear that organic aerosols constitute a significant fraction of overall fine particle mass in many urban locales. Together with other sources of organic compounds – notably highway and nonroad diesel-powered engines – light duty vehicles are therefore likely to play at least some role in the formation of fine particle pollution in most urban areas.

In this context, any additional hydrocarbon reductions[23] achieved through the California LEV program will help states address the formidable challenge of attaining (and maintaining) new ozone and fine particle ambient air quality standards despite continued growth in vehicle miles traveled and other pollution-generating activities. More importantly, resulting air quality improvements will translate to potentially significant public health benefits, especially for the millions of citizens who live in urban areas of the Northeast that frequently experience unhealthy concentrations of ozone and fine particle pollution

C. Climate Benefits

In the Northeast, emissions from gasoline-powered vehicles account for approximately 30 percent of total GHG emissions, compared to a national average of approximately 22 percent. The transportation sector not only accounts for a large share of overall GHG emissions in the region, its contribution has increased more rapidly than that of other sectors in recent decades. That trend – spurred by ever-increasing vehicle miles traveled and flat or declining fleet fuel economy – looks set to continue, with the transportation sector projected to account for most of the growth in overall GHG emissions in the Northeast in coming years as well. At the same time, states face particular challenges in addressing emissions from this sector, given the difficulty of reducing transportation demand and the fact that federal pre-emption precludes direct state regulation of automobile fuel economy. In light of existing state and regional commitments to address climate concerns, the modest greenhouse gas emissions reductions associated with the advanced technology component of the California program therefore represent another benefit of LEV II compared to the federal program. These

[23] Note that while both LEV II and Tier 2 will achieve very substantial reductions in NOx emissions relative to current vehicles, there is only a minimal difference in stringency between the two programs with respect to this pollutant. Given that the difference in NOx requirements is so small, we did not seek to evaluate the NOx benefits of LEV II relative to Tier 2.

benefits could become more significant over time if advanced technology vehicle requirements lead to the mass commercialization of next-generation vehicle technologies that can achieve substantially reduced GHG as well as criteria pollutant emissions.

A brief summary of other state efforts related to climate change – in the Northeast and elsewhere – follows:

- In 2001, the Conference of New England Governors and Eastern Canadian Premiers (NEGC/ECP) adopted a climate action plan with specific regional GHG reduction targets. Specifically, the NEGC/ECP plan calls for returning regional emissions to 1990 levels by 2010 with further reductions (to 10% below 1990 levels by 2020 and to sustainable levels – i.e. 75-85% -- in the longer term) to follow.

- New Jersey adopted a target to reduce greenhouse gases 3.5 percent below 1990 levels by the year 2005 and 7 percent below 1990 levels by 2010.

- New York recently announced an energy plan with a goal of reducing GHG emissions 5 percent below 1990 levels by 2010 and 10 percent below 1990 levels by 2020. As part of the plan, renewable energy use will increase from the current level of 10 percent to 15 percent by 2020.

- Other states have proposed or adopted specific greenhouse gas reduction targets for other sectors, notably for the power sector. For example, Oregon, Massachusetts and New Hampshire have established specific GHG requirements for power plants; and Washington State is expected to follow suit in the near future. In addition, New York governor George Pataki has proposed a regional carbon cap for power plants from Maryland to Maine.

- Under legislation passed in 2002, the California Air Resources Board is required to adopt "regulations that achieve the maximum feasible reduction of GHG emissions" from passenger vehicles by January 2005. The regulations would affect new cars starting in model year 2009 and thereafter.

D. Conclusions

The LEV II program provides significant toxic and CO_2 emission reductions over the Tier 2 program. Unlike the federal program which will remain the same for at least a decade (as is required by the Clean Air Act) the California program will probably continue to become more stringent. Thus emissions differences between the California and federal programs will likely become greater as California adopts more stringent phases of the LEV program. In particular, risks associated with exposure to toxics such as benzene, formaldehyde, and 1,3-butadiene will be significantly reduced by adoption of the California LEV II program.

V. Overview of the LEV II and Tier 2 Programs

This section provides additional information on the differences between the Tier 2 and the LEV II programs. Both programs require manufacturers to certify passenger cars to individual vehicle tailpipe emissions and evaporative standards. In addition, automobile manufacturers must meet a fleet-wide emissions average in each year. Manufacturers are given the flexibility to produce vehicles meeting any set of standards so long as their sale-weighted average complies with declining emissions average requirements.

A. LEV II Program Summary

California's program establishes a declining fleet average for non-methane organic gas (NMOG) emissions. The fleet average NMOG requirement is reduced each year until 2010 when the requirement for passenger cars will be .035 grams per mile and .043 for heavier trucks. California has established four categories or "bins" of emissions standards that automobile manufacturers can certify vehicles to. These are LEV, ULEV, SULEV and ZEV. Standards corresponding to each bin are summarized in Table 2.

Table 2. LEV II Exhaust Mass Emission Standards for New 2004 and Subsequent Model Year Passenger Cars

Vehicle Type	Durability Vehicle (miles)	Vehicle Emission Category	NMOG (g/mi)	Carbon Monoxide (g/mi)	Oxides of Nitrogen (g/mi)
All passenger cars and light duty trucks 8,500 lbs. GVW or less	50,000	LEV	0.075	3.4	0.05
		LEV, option 1	0.075	3.4	0.07
		ULEV	0.040	3.4	0.05
	120,000	LEV	0.090	1.7	0.07
		LEV option 1	0.090	4.2	0.10
		ULEV	0.055	2.1	0.07
		SULEV	0.010	1.0	0.02
	150,000 (optional)	LEV	0.090	4.2	0.07
		LEV option 1	0.090	4.2	0.10
		ULEV	0.055	2.1	0.07
		SULEV	0.010	1.0	0.02

In addition to the emission standards outlined above, the California LEV program requires that, beginning in 2005, 10 percent of cars sold by large volume manufacturers must be "advanced technology vehicles." Advanced technology vehicles include vehicles with zero tailpipe and evaporative emissions (ZEVs), vehicles that have some electric drivetrain components (advanced technology partial ZEVs or AT PZEVs), and conventional gasoline vehicles that meet certain emissions, durability, and warranty requirements (called partial ZEVs or PZEVs).[24] Recent changes to the ZEV mandate greatly reduce the number of pure ZEVs required to meet the mandate.

The current ZEV program allows manufacturers to follow one of two compliance paths. The conventional path maintains the 2 percent ZEV, 2 percent AT PZEV and 6 percent PZEV requirement that was established in 2001. Manufacturers can use banked credits to satisfy the ZEV requirement. The second or "alternative compliance" path allows manufacturers to meet the entire 10 percent ZEV mandate with AT PZEVs (such as hybrid electric vehicles) and PZEVs. Manufacturers who choose the alternative compliance path must produce a small number of fuel cell or battery electric vehicles.[25]

B. Tier 2 Program Summary

Like California's LEV II program, the federal Tier 2 program requires manufacturers to certify individual vehicles to tailpipe and evaporative emissions standards and to meet a sales-weighted fleet-wide emissions average. However, the Tier 2 program differs from LEV II in that it requires manufacturers to meet a fleet wide average for NOx rather than NMOG. Emissions standards for individual vehicles are listed below in Table 3. The Tier 2 fleet-wide average NOx standard is .07 grams per mile. This corresponds to a bin 5 vehicle, although manufacturers can certify vehicles in any bin as long as they meet the fleet wide average.

[24] All vehicles that qualify for ZEV credit must meet the SULEV tailpipe emissions standards at 150,000 miles, satisfy second-generation on-board diagnostics requirements (OBD II), have zero evaporative emissions and carry an emission warranty covering all malfunctions identified by the OBD II system for 15 years or 150,000 miles.

[25] The requirement is for all manufacturers combined to produce 250 ZEV vehicles (a combination of fuel cell and/or battery electric vehicles) between 2005 and 2008. The number of ZEV vehicles required increases in 2009 - this number has not been determined.

Table 3. Tier 2 Full Useful Life Exhaust Mass Emission Standards

Bin #	NOx	NMOG	CO	HCHO
11*	.9	.280	7.3	0.032
10*	.6	0.156/0.230	4.2/6.4	0.018/0.027
9*	.3	0.90/0.180	4.2	0.018
8	0.20	0.125/0.156	4.2	0.018
7	0.15	0.090	4.2	0.018
6	0.10	0.090	4.2	0.018
5 (LEV)	0.07	0.090	4.2	0.018
4	0.04	0.070	2.1	0.011
3	0.03	0.055	2.1	0.011
2 (SULEV)	0.02	0.010	2.1	0.004
1 (ZEV)	0.00	0.000	0.0	0.000

C. Evaporative Standards Under the LEV II and Tier 2 Programs

Table 4 details the 2-day and 3-day evaporative emissions standards required under the federal and California programs.

Table 4. Evaporative Emissions Standards for LEV II and Tier 2

Vehicle Class	2-day/3-day diurnal + hot soak test standard in grams/test	
	California	**Federal**
Passenger cars	.65/.5	1.2/.95
Light duty trucks <6,000 lbs GVW	.85/.65	1.2/.95
Light duty trucks 6,000-8,500 lbs GVW	1.15/.9	1.5/1.2
Medium duty vehicles under 10,000 lbs. GVW	1.25/1.0	1.75/1.4

Table 4 shows that the LEV II program evaporative standards are more stringent than the Tier 2 evaporative standards. In addition to the above evaporative standards, ZEV, AT PZEVs and PZEVs must meet a zero evaporative emission standard. The California Air Resources Board estimates that by 2010 over 37 percent of the vehicles sold in LEV states will be subject to the zero evaporative emissions standard.

* Bin 11 is only for medium duty passenger vehicles and will be deleted at the end of 2008. Bin 10 and higher NMOG, CO and HCHO values apply for certain vehicles and will be deleted at the end of 2006 or 2008 (depending on the vehicle type). Bin 9 and higher NMOG standards apply only to certain vehicles will be deleted at the end of 2006 or 2008 (depending on the vehicle).

VI. Methodology and Assumptions Used to Calculate Emissions Reduction Benefits for the LEV II and Tier 2 Programs

This section describes the methodology used to estimate emissions reductions achieved by the adoption of the LEV II program in New York, Massachusetts, and Vermont relative to emissions under the Tier 2 program. As indicated previously, modeling analyses were performed to predict future HC, toxics and CO_2 emissions from the motor vehicle fleet in New York, Massachusetts and Vermont under both the LEV II program and the federal Tier 2 program. Light duty vehicles weighing less than 6,500 lbs were included in the analysis. Heavier vehicles in light duty truck categories 3 and 4 were not included in the analysis since these vehicles are not affected by the ZEV mandate. Assumptions about the emissions performance of light-duty vehicles under the federal base case and the California LEV II program were input to MOBILE6, EPA's most recent mobile source emission factor model, to estimate how motor vehicle fleet emission rates might differ under the two programs. Assumptions concerning the CO_2 emissions characteristics of different vehicles were taken from the Argonne National Laboratory's GREET model.[26] These emissions assumptions were then combined with estimates of future light-duty vehicle travel in the three states to predict future emission levels for two projection years (2010 and 2020).

Key assumptions are discussed for: (1) overall program structure and vehicle sales mix; (2) approach to estimating toxics emissions; and (3) approach to estimating CO_2 and other greenhouse gas (GHG) emissions.

A. Program Structure and Sales Mix

Under the California LEV II program, the ZEV requirement begins in 2005 (at the time this analysis was done, the ZEV component was to begin in 2003), with the requirement that the new vehicle fleet include a minimum of 10 percent ZEVs or equivalent as obtained through ZEV credits. The ZEV credit requirement increases from 10 to 16 percent between model years 2009 and 2018, and remains at 16 percent thereafter. In any given year, a maximum of 6 percent of the ZEV credit may be obtained through PZEVs; at least half of the remaining credit (2 percent in 2008 and 5 percent in 2018) must be obtained through ZEVs. The rest can be obtained with AT PZEVs.
In this analysis, the Northeast ZEV requirement was assumed to begin in 2004. Under the Northeast ZEV program, manufacturers have the option of meeting a phase-in schedule known as the Alternative Compliance Plan (ACP).[27] Under the ACP, a smaller number of ZEVs are required in the early years and additional credit multipliers are

[26] The GREET model (Greenhouse Gases, Regulated Emissions, and Energy use in Transportation) was developed by Argonne National Laboratory. It allows researchers to estimate emissions of CO2 equivalent GHGs, consumption of total energy, and emissions of five criteria pollutants. The model allows researchers to evaluate various engine and fuel combinations on a consistent fuel-cycle basis.
[27] "Structure for the ZEV Alternative Compliance Plan," December 26th, 2001.

provided for early implementation (years 2002 through 2006). The ZEV requirement will be synchronized with the California requirement beginning in model year 2007.

Because manufacturers can use different strategies to comply with the ZEV mandate, NESCAUM analyzed several different compliance scenarios for this component of the LEV II program. Table 5 describes the five scenarios analyzed, showing the percentage of ZEV *credits* obtained by vehicle type in 2007 and 2008 (not the actual percentage of vehicles produced) for the LEV II scenarios. The scenarios are described as follows:

- Scenario 1 – Transition from current LEV I to Federal Tier 2 implementation in 2004 through 2006, consistent with the national Tier 2 phase-in schedule.
- Scenario 2 – LEV II implementation with automakers meeting the minimum two percent ZEV credit and two percent AT PZEV requirement.
- Scenario 3 – LEV II implementation with automakers meeting the minimum two percent ZEV credit, and meeting half the remaining credits with AT PZEVs and half with PZEVs.
- Scenario 4 – LEV II implementation with automakers meeting the full ZEV credit requirement with full-function ZEVs.
- Scenario 5 – LEV II implementation with automakers meeting the full ZEV credit requirement with ZEVs, where half the credits are met with full-function ZEVs (FFEVs) and half are met with smaller "city" electric vehicles (CEVs) that have limited speed and range.

Table 5. Scenarios Analyzed for Tier 2 and LEV II Implementation

		ZEV –FFEV	ZEV - CEV	AT PZEV	PZEV
Scenario	Program	Full-Function Zero-Emission Vehicles	City Electric Vehicles	Advanced Tech. Partial ZEVs	Partial ZEVs
1	Tier 2				
2	LEV II	2%		2%	6%
3	LEV II	2%		4%	4%
4	LEV II	10%			
5	LEV II	5%	5%		

Note that under Scenarios 3, 4 and 5, a hypothetical "ramp-up" schedule is established to smoothly increase the ZEV percentage in 2004 through 2007.

Table 6 shows the ZEV credits assumed for each type of vehicle by model year. These assumptions are consistent with assumptions made by staff of the California Air Resources Board (CARB) in a developing a worksheet of hypothetical sales scenarios, with adjustments for model years 2003 through 2006 to reflect early implementation credits under the Alternative Compliance Plan.[28] Obviously, the breakdown of credits in future years cannot be predicted with certainty, since it will depend on the mix of actual vehicles produced by automakers.

Table 6. Assumed ZEV Credits by Vehicle Type

Model Year	ZEV – FFEV	ZEV - CEV	AT PZEV	PZEV
2003	10.63	4.00	3.72	1.20
2004	10.63	4.00	1.86	0.60
2005	7.04	2.89	1.07	0.35
2006	5.59	2.64	0.71	0.23
2007	3.75	1.99	0.62	0.20
2008	3.44	1.38	0.54	0.20
2009	3.34	1.40	0.54	0.20
2010	3.20	1.42	0.54	0.20
2011	3.20	1.42	0.54	0.20
2012 - 2020	2.90	1.40	0.54	0.20

A detailed spreadsheet file showing the assumed mix of light-duty vehicles and trucks under the different scenarios analyzed is included as Appendix A. Note that while our assumptions for the heavier class of light-duty trucks (LDT2) are included in the spreadsheet, these assumptions actually do not vary by scenario since LDT2 vehicles are not directly subject to the ZEV requirement.[29] Assumptions about vehicle mix were designed to meet the LEV program's NMOG targets, thereby providing a fair comparison among scenarios, and do not necessarily represent an actual sales mix scenario that might be implemented by automakers. Note that under Scenarios 2 and 3, however, technology requirements force the NMOG average below the required target for the model year.

Separate mixes were calculated for New York and Massachusetts, since the automobile vs. light truck share of the overall light-duty vehicle sales base is expected to be significantly different in New York.[30] Since the proportion of automobiles in Vermont is forecast to be close to that of Massachusetts and since Vermont has much lower VMT than New York or Massachusetts, the Massachusetts sales mix assumptions were also

[28] As obtained from Paul Hughes, April 2002.

[29] Light-duty vehicles (LDV) include all passenger cars. Class 1 light-duty trucks (LDT1) include trucks up to 3,750 lb. gross vehicle weight rating (GVWR). LDV and LDT1 must meet the same emissions standards and ZEV requirements under the California program. Class 2 light-duty trucks (LDT2) include trucks between 3,750 and 6,000 lb. GVWR. These vehicles must meet less stringent NMOG fleet certification average and evaporative standards, and do not need to generate ZEV credits. However, the California ZEV program now requires that beginning with a phase-in period from 2007 through 2011, LDT2 vehicles must be included in a manufacturer's sales base for calculating the required number of ZEV vehicle credits.

[30] Based on "fleet implementation calculator" information received from the states via NESCAUM in May 2002, the estimated percentage of automobiles (LDV) of all light-duty vehicles (LDV + LDT1 + LDT2) is 69 percent in New York, 60 percent in Massachusetts and 62 percent in Vermont.

used for the Vermont analysis. As a result, because the New York sales base for calculating ATV sales requirements is not expanded as much as the Massachusetts or Vermont sales bases (i.e., the percentage of LDT2 vehicles forecast in New York is smaller), the required percentage of ATV sales within the LDV + LDT1 fleet is correspondingly smaller. For example, Scenario 2 assumes 54 percent PZEV and 11 percent AT PZEV sales in New York in 2020, compared to 68 percent and 12 percent (respectively) in Massachusetts and Vermont.

B. Calculation of Air Toxics Emissions

Emissions of air toxics were estimated based on VOC emissions predicted by the MOBILE6 model. For each scenario, an implementation schedule (94+ LDG IMP and T2 EXH PHASE-IN files) was defined consistent with the sales mix assumptions shown in Appendix A. A corresponding set of 50,000-mile certification standards (T2 CERT file) was also included for the CA LEV implementation schedules.

VOC exhaust and evaporative emissions outputs from the MOBILE6 model were then multiplied by toxics fractions for four air toxics: benzene, formaldehyde, acetaldehyde and 1,3 butadiene. (Of these four, only benzene is released with evaporative emissions.) The toxics fractions used in this study were taken from recent research by the U.S. Department of Energy,[31] which provides updated information compared to the factors reported by EPA using its Complex model.[32] The toxics ratios assumed for purposes of this analysis are shown in Table 7.

As this analysis was being conducted, EPA released a new draft version of MOBILE6 (MOBILE 6.2) that reports toxics emissions. However, EPA reports that the toxics ratios used in this model are still based on the early-1990s research referenced above and have not been updated. Therefore, we felt it appropriate to use the more recent DOE fractions for this analysis.

Table 7. Ratio of Toxic Emissions to Total VOC Emissions

Exhaust				Evaporative
Benzene	1-3 Butadiene	Formaldehyde	Acetaldehyde	Benzene
0.0564	0.0062	0.0125	0.00048	0.0113

1. MOBILE6 Inputs

The MOBILE6 model has only recently been released, and each of the Northeast states is in the process of developing MOBILE6 input files. Where available, state-specific data were used for inputs that would have a potentially significant impact on the

[31] U.S. Department of Energy. Argonne National Laboratory. *Fuel-Cycle Emissions for Conventional and Alternative Fuel Vehicles: An Assesment of Air Toxics,* August 2000.

[32] U.S. EPA. *Final Regulatory Impact Analysis for Reformulated Gasoline*, December 1993.

results, such as inspection and maintenance (I/M) programs. Emission factors were developed separately for four regions:

- Massachusetts
- New York "downstate" (primarily the New York City metropolitan area)[33]
- New York "upstate" (rest of New York State)
- Vermont

State-specific inputs were used for fuel and temperature parameters. State-specific I/M program inputs were also used for Massachusetts. Since MOBILE6 I/M files were not yet available from New York State, Massachusetts I/M program inputs — which represent a centralized I/M program— were used for downstate New York. Upstate New York and Vermont do not have I/M programs, and therefore no I/M program inputs were used in these cases.

With the exception of these inputs, national defaults embedded in MOBILE6 were used for other model parameters. The use of defaults rather than state-specific assumptions in these instances is unlikely to create a significant difference in the relative benefits calculated for the LEV II vs. Tier 2 programs.

2. Effect of Extended Durability Requirements

The California ZEV program requires that all vehicles obtaining ZEV credits, including PZEVs and AT PZEVs, be certified to 150,000-mile durability standards instead of 120,000-mile standards as required for Tier 2 and other LEV II vehicles. Since PZEVs are expected to make up a significant percentage of the vehicle fleet, this requirement is likely to lead to additional reductions in VOC and toxics emissions beyond those estimated in the current analysis. The benefits of the 150,000-mile standard were not estimated in this study for two reasons. First, solid information to quantify these benefits was not readily available. CARB has developed a methodology for estimating increases in emissions over vehicle life ("deterioration rates") as embedded in its EMFAC2000 model, but the methodology is not directly transferable to the calculation of emissions in the MOBILE6 model. Second, the effects of the durability standard are likely to be related to the specific I/M programs in place and to the effectiveness of I/M and on-board diagnostics (OBD) in identifying and repairing high-emitting vehicles. The status of I/M program varies in the Northeast; Massachusetts and downstate New York have enhanced I/M programs, while upstate New York and Vermont currently have no I/M program. Therefore, the benefits of the enhanced durability standard may vary across the region.

3. Evaporative Emissions

The Tier 2 program phases in more stringent evaporative emissions standards that reduce diurnal + resting loss evaporative emissions by roughly 50 percent compared to

[33] The downstate counties include New York, Kings, Queens, Bronx, Richmond, Nassau, Suffolk, Westchester, Rockland, and Putnam.

Tier 1 and LEV I vehicles. The California LEV II program includes even more stringent evaporative emissions standards that are about 75 percent lower than the certification standard for Tier 1 and LEV I vehicles. In addition, all vehicles that achieve ZEV credits (ZEVs, PZEVs and AT PZEVs) must be certified to "near-zero" evaporative emissions standards. These standards are shown in Table 8a. The LEV II program also has a slightly more advanced phase-in schedule for its evaporative standards than the Tier 2 program (also shown in Table 8b).

Table 8a. Evaporative Emissions Standards

Three-Day Diurnal + Hot Soak Emissions, g/test

Vehicle Class	Tier 1/LEV I	Tier 2	LEV II	LEV II PZEV/ZEV
LDV	2.00	0.95	0.50	0.35
LDT1, LDT2	2.00	0.95	0.65	0.50

Table 8b. Phase-in Schedule for Enhanced Evaporative Standards

Model Year	Tier 2	LEV II
2003	0%	0%
2004	25%	40%
2005	50%	80%
2006	75%	100%
2007	100%	100%

Because MOBILE6 is not capable of modeling enhanced evaporative emissions standards beyond the Tier 2 requirements, post-processing adjustments of MOBILE6 output were made to account for the LEV II standards. To do this, evaporative emissions outputs for Tier 2 vehicles were obtained by model year. For LEV II and LEV II advanced technology vehicles, evaporative emissions were then reduced in proportion to the ratio of LEV II to Tier 2 certification standards. These ratios are shown in Table 8c. The proportions in model years 2004 through 2006 reflect the different phase-in schedules for the two programs as well as the different certification standards being introduced.

Table 8c. Ratio of Evaporative Emissions for LEV II vs. Tier 2 Vehicles

	LEV II		LEV II zero-fuel evap. (PZEV, AT PZEV)	
Model Year	LDV	LDT1 & 2	LDV	LDT1 & 2
2003	1.00	1.00	1.00	1.00
2004	0.81	0.84	0.77	0.81
2005	0.54	0.62	0.46	0.54
2006	0.41	0.54	0.29	0.41
2007 - 2020	0.53	0.68	0.37	0.53

It is possible that the LEV II evaporative standards could lead to actual reductions in emissions that are either larger or smaller than the proportionate reduction in certification standards. One case in which benefits might be smaller is if the proportion of high emitters (e.g., due to component failures) is not reduced in proportion to the change in certification standards. However, it is also likely that the technology introduced to meet the enhanced and near-zero evaporative standards will be less prone to failure than the technologies currently in use. A recent report by CARB staff suggests that the enhanced evaporative standards already introduced under the LEV I program have reduced the incidence of high emitters by about 50 percent. An additional reason why the proportional adjustment method could underestimate benefits is because the "near-zero" vehicles (including all PZEVs and AT PZEVs) must be certified to 150,000-mile durability standards instead of 120,000-mile standards. The greater durability requirement is likely to lead to lower evaporative emissions over the life of the vehicle. Furthermore, the more stringent evaporative emissions standards may help to reduce other sources of evaporative emissions, including resting, running, and crankcase emissions, not covered in the diurnal + hot soak test.

As mentioned previously, the approach used to estimate evaporative emissions in this report differs from that used by EPA in a previous analysis of the emissions benefits of the LEV II program. EPA's analysis assumed that cars sold in all 50 states will meet LEV II evaporative emissions standards. In addition, EPA assumed that no vehicles under the LEV scenario would meet the near-zero evaporative emissions standards required of advanced technology vehicles. In this analysis, by contrast, we assume that advanced technology vehicles will meet near-zero evaporative emissions standards. We also assume that cars in the Tier 2 program cars will be certified to Tier 2 evaporative standards, and not LEV II evaporative standards.

C. Calculation of Vehicle-Miles of Travel

To calculate total emissions emission factors were combined with estimates of vehicle-miles of travel (VMT) for each region analyzed. For New York State, current VMT estimates and 2010 and 2020 forecasts were obtained by county and vehicle type from the Department of Environmental Conservation (NYDEC). Consistent with MOBILE6, VMT estimates were developed separately for upstate and downstate New York. For Massachusetts, forecasts of total VMT were obtained from the state through 2020; these were allocated to different vehicle types based on EPA forecasts which account for the growing percentage of light trucks in the light-duty vehicle fleet.[34] For Vermont, no official forecasts of 2010 or 2020 VMT were available, so total VMT estimates were extrapolated from historical data provided by the state and allocated by vehicle type using the same methodology as for Massachusetts. VMT estimates by state, year and vehicle type are shown in Table 9.

Table 9. VMT Estimates (Daily, in Millions of Miles)

Calendar Year	LDV	LDT1	LDT2
Massachusetts			
2003	68.9	51.7	17.2
2010	60.0	69.2	23.1
2020	57.6	86.2	28.7
Vermont			
2003	10.5	7.9	2.6
2010	8.7	10.1	3.4
2020	7.7	11.5	3.8
New York - Upstate			
2003	112.4	64.2	35.2
2010	129.8	74.3	40.7
2020	151.6	86.8	47.7
New York - Downstate			
2003	90.2	53.0	31.5
2010	103.5	60.7	36.2
2020	120.1	70.4	42.0

D. Calculation of Greenhouse Gas Emissions

The GREET Model Version 1.5a, developed by Argonne National Laboratory and the University of Chicago, was used to calculate CO_2 and other GHG emissions for different vehicle technologies. GREET is a full-fuel-cycle model that accounts for "upstream" emissions in the production and transport of fuel, as well as "downstream" emissions resulting from vehicle operation. GREET was used with its default inputs, with two primary exceptions: first, custom assumptions were developed for the relative efficiencies of various vehicle technologies; and second, an electricity generating mix specific to the Northeast was used. These and other key assumptions used in this modeling process are discussed in more detail below.

[34] The methodology for allocating Massachusetts VMT by vehicle class is the same as used in the 1999 study by Cambridge Systematics for NESCAUM of the benefits of the CA LEV II program.

1. Vehicle Technology Assumptions

PZEV vehicles are assumed to be conventional gasoline engine vehicles with advanced emissions control technology. Approximately ten production vehicles have already been certified to PZEV standards, so it is assumed that other gasoline-engine vehicles will be able to meet this standard as well.

Advanced technology vehicles (AT PZEVs and ZEVs) are assumed to be the following:

- AT PZEVs are assumed to be grid-independent gasoline-electric hybrids, similar to the Honda Insight or Toyota Prius which are being sold today. These vehicles do not yet meet all of the PZEV criteria, but are expected to in the near future.

- ZEVs are assumed to be battery-electric vehicles through 2009, transitioning to hydrogen fuel cell vehicles (H2FC) between 2010 and 2013. Hydrogen fuel is assumed to be produced from natural gas at centralized power plants.

Numerous other vehicle/fuel technologies could have been evaluated. For example, alternative-fuel vehicles running on compressed natural gas (CNG), liquid propane gas (LPG) or methanol could potentially meet the AT PZEV standards. "Grid-connected" hybrid vehicles can obtain additional credits for a zero-emission range (running on batteries) of 20 to 60 miles. Fuel cell vehicles may also be powered by methanol or gasoline via an on-board reformer, although these would not necessarily meet ZEV standards. The technologies evaluated here were selected because they were viewed as the most likely to be commercialized among the technologies capable of meeting California ZEV requirements.

2. Energy Efficiency

CO_2 emissions depend upon both the consumption of energy (upstream and downstream) to power the vehicle and the carbon content of the fuels used in this process. Energy efficiency can be thought of in two separate components:

- The efficiency of energy use by the vehicle, i.e., the distance traveled per unit of energy (British thermal unit or kilowatt-hour) in the fuel that is put into the vehicle.

- The overall efficiency of the fuel production process, including extraction, generation and transmission.

The energy efficiency ratio (EER) of advanced technology vehicles to conventional gasoline vehicles is one of the required inputs of the GREET model. Energy efficiency is measured as the energy content of the fuel used in operating the vehicle per unit distance traveled. It can be thought of as a miles-per-gallon (MPG) equivalent. The EER does not reflect upstream energy consumption, which is estimated separately in the GREET model.

EERs for ATVs are somewhat uncertain given the emerging nature of the technologies being developed. To identify appropriate EERs for this analysis, a literature review was undertaken. Experts were contacted and reports reviewed from organizations involved in advanced vehicle technology research, including the Office of Transportation Technologies at the Department of Energy, the Center for Transportation Research at Argonne National Laboratory, the California Air Resources Board and the Institute of Transportation Studies at the University of California at Davis.

The following EERs were selected for this analysis:

- **Hybrid-electric vehicles (AT PZEVs):** 1.4:1. This is approximately the ratio of fuel economy on the EPA combined cycle for the 2003 Honda Civic hybrid compared to the automatic-transmission gasoline Civic, and for the Toyota Prius compared to the automatic-transmission Toyota Corolla.[35] Hypothetical evaluations of a compact, midsize and SUV hybrid by Argonne National Laboratory also show an EER of about 1.4.[36] The anticipated Ford Escape hybrid, a small sport-utility vehicle, is rumored to obtain 35 MPG, which gives it an EER of 1.6 compared to the V6 Escape.

- **Battery-electric vehicles (ZEVs)**: 2.65:1. This is the midpoint of a range of values (2.4 to 2.9) estimated by Arthur D. Little in a report to the California Air Resources Board on projections of battery-electric EERs for both the short term and the long term.[37] Other comparisons of actual battery-electric vehicles with similarly-sized gasoline vehicles typically show EERs in the range of 2 to 4, so 2.65 is viewed as a reasonably conservative estimate.[38]

- **Hydrogen fuel cell vehicles (ZEVs)**: 2.6:1. EERs for fuel-cell vehicles are somewhat more speculative since production-ready vehicles do not yet exist and fuel cell systems are still undergoing rapid development. However, the Department of Energy (DOE) has evaluated the efficiency of hydrogen fuel-cell systems.[39] Current and projected efficiency for such a system is estimated to

[35] U.S. Department of Energy and U.S. Environmental Protection Agency. "Model Year 2002 Fuel Economy Guide." DOE/EE-0250. Internet: www.fueleconomy.gov
[36] Argonne National Laboratory and Electric Power Research Institute. "EPRI Hybrid Electric Vehicle Working Group: HEV Costs and Emissions." Downloaded May 3, 2002. from: www.transportation.anl.gov/ttrdc
[37] Unnasch, Stefan, and Louis Browning. "Refinement of Selected Fuel-Cycle Emissions Analyses." Prepared for CARB by Arther D. Little, February 2000.
[38] c.f. Singh, Margaret. "Total Energy Cycle Use and Emissions of Electric Vehicles." Prepared for Transportation Research Board Annual Meeting, January 1999; EPA Green Vehicle Guide, www.epa.gov/autoemissions/about.htm, April 2002; U.S. Department of Energy. "Fleet Testing - (Task 4) Final Report." Prepared by Electric Transportation Applications, July 2001.
[39] U.S. Department of Transportation. "Fuel Cells for Transportation: FY 2001 Progress Report." www.cartech.doe.gov/research/fuelcells/

range from 55 to 60 percent of the energy content of the fuel, as compared to 20 to 25 percent for a gasoline engine (running at 25 percent power output). This suggests an EER of about 2.6.

As a baseline to compare energy use, conventional gasoline vehicle fuel economy was assumed to remain constant over the period of the analysis. Average fuel economy by vehicle class has remained roughly constant over the past decade, and in the absence of policy initiatives to raise fuel efficiency standards or a sustained, long-term increase in the price of oil, this trend is expected to continue. Average fuel consumption rates by vehicle class included in the GREET model, as derived from DOE estimates, are 22.4 MPG for LDVs and 16.8 MPG for LDT1 and LDT2 (up to 6,000 lb. GVWR).

3. Emissions from Powerplants

The GREET model was also used to estimate CO_2 emissions from electricity-generating powerplants. A mix of fuel types specific to New England was used in place of the GREET model defaults, based on recent data from the Energy Information Administration (EIA).[40] This mix is shown in Table 10. "Other" fossil fuels, including municipal solid waste, tires and other fuels, make up 4.5 percent of this mix; for the purposes of the GREET model, these fuels were included in the same category as residual oil. Other key assumptions include the percentage of natural gas and coal electricity generation from combined cycle (CC) plants, which are considerably more efficient than other plants. In this analysis, 45 percent of natural gas and 20 percent of coal generating capacity, the default values contained in GREET, is assumed to be from combined cycle plants. In this analysis, no distinction is made between "marginal" and "average" emissions rates.

Table 10. Mix of Fuels for Electricity Generation

Fuel Type	Percent
Residual Oil and "Other" Fossil Fuel	27.5%
Natural Gas	18.0%
Coal	16.3%
Non-Fossil	38.2%
Total	100.0%

The electricity generation mix for the Mid-Atlantic region, which includes New York state, is significantly different (including more coal and non-fossil fuels and less residual oil) than that of New England, but produces nearly identical CO_2 emissions

[40] U.S. Department of Energy and U.S. Environmental Protection Agency. "Carbon Dioxide Emissions from the Generation of Electric Power in the United States," July 2000. www.eia.doe.gov

according to the EIA. Hence, for simplicity, the New England mix was used throughout this analysis.

The future electricity generating mix may be affected by a number of factors, including prices of different fuels, regulatory conditions, market demand and technological developments, which are difficult to forecast. In the absence of reliable forecasts, the mix is assumed to remain the same in future years for purposes of this analysis. This assumption may overestimate GHG emissions from electric vehicles in future years, since GHG emissions from New England powerplants have been declining slightly given trends toward greater reliance on natural gas (which has a lower carbon content) and renewable resources as well as more efficient technology. In addition, several Northeast states have adopted policies or regulations aimed at reducing future power sector GHG emissions.

4. City Electric Vehicles

Two different scenarios of electric vehicle sales were evaluated, one including all full-function EVs (FFEVs) and one including primarily "city" EVs. CEVs typically are two-passenger vehicles with a maximum range of 55 to 70 mph and a range of 50 to 80 miles.[41] CEVs might produce different emissions impacts than FFEVs for a number of reasons:

- CEVs may be driven a shorter average distance than a typical vehicle, since it is likely to be used primarily for urban trips, which are shorter on average than other trips, and because its range and speed is limited.
- CEVs are smaller than the average vehicle, and therefore replace compact conventional vehicles at the more fuel-efficient end of the vehicle fleet. The resulting GHG emissions benefit per vehicle would be less than the benefit for an average-sized FFEV with the same energy efficiency ratio.
- CEVs are likely to operate primarily on urban driving cycles, where electric vehicles have a greater relative efficiency advantage over conventional gasoline vehicles. In contrast to the previous two points, this effect would tend to magnify the CO_2 reductions achieved by CEVs relative to FFEVs.

To account for the lesser range of CEVs, an adjustment was made. To estimate VMT under urban conditions, data from the 1995 Nationwide Personal Transportation Survey (NPTS) were used. Specifically, an analysis of the NPTS data showed that average VMT per capita in urban locations (defined based on a set of population density measures) was 62.5 percent of average VMT per capita in all locations (5,359 vs. 8,523

[41] California Air Resources Board. "Staff Report: 2000 Zero Emission Vehicle Program Biennial Review." August 2000, p. 54.

miles per year).[42] VMT totals were therefore allocated between CEVs and other LDVs to maintain this same proportion of VMT per vehicle.

In the current analysis, adjustments were not made for vehicle size class efficiency or for urban driving cycles. A review of class-average fuel economy shows that CAFE combined-cycle MPG for compact cars is around 30, not significantly different from the LDV class average of 28.5. Also, the effects of vehicle size and driving cycle are likely to somewhat offset each other.

5. GHG Emission Rates

The results of the GREET model for energy consumption, CO_2 emissions, and total GHG emissions for the different technologies evaluated are shown in Tables 11a and 11b. Table 11b shows the GHG emissions factors used by model year for each vehicle class, based on a phase-in transition from battery-electric to fuel cell vehicles between 2010 and 2013.

Table 11a. Energy Consumption and Greenhouse Gas Emissions[43]

	Total					**Percent Change Relative to Conv. Gasoline**		
Total	**Conv. gasoline**	**Hybrid-electric**	**Battery-electric**	**Hydrogen fuel cell**		**Hybrid-electric**	**Battery-electric**	**Hydrogen fuel cell**
LDV								
Total energy (Btu/mi)	6,347	4,534	6,138	3,277		-29%	-3%	-48%
CO_2 (g/mi)	448	320	311	188		-29%	-31%	-58%
GHGs (g/mi CO_2 equiv.)	473	341	322	194		-28%	-32%	-59%
LDT1, LDT2								

[42] Ross, Catherine L., and Anne E. Dunning. "Land Use Transportation Interaction: An Examination of the 1995 NPTS Data." Prepared for U.S. Department of Transportation by the Georgia Institute of Technology, October 1997.

[43] The complete technology packages evaluated using the GREET model are as follows:
1) Conventional gasoline vehicle on Federal stage 2 reformulated gasoline (FRFG2)
2) Grid-independent SIDI HEV on FRFG2
3) Battery electric vehicle
4) Fuel cell vehicle: hydrogen, gaseous, natural gas

Total energy (Btu/mi)	6,347	4,534	6,138	3,277		-29%	-3%	-48%
CO_2 (g/mi)	448	320	311	188		-29%	-31%	-58%
GHGs (g/mi CO_2 equiv.)	473	341	322	194		-28%	-32%	-59%

Table 11b. GHG Emissions Rates Used in Analysis (g/mi CO_2 equivalent)

Model Year	FFEV Technology			LDV			LDT1, LDT2		
	BEV	H2FC		ZEV	AT PZEV	All Other	ZEV	AT PZEV	All Other
<=2003						473			473
2004	100%	0%		322	341	473	322	341	473
2005	100%	0%		322	341	473	322	341	473
2006	100%	0%		322	341	473	322	341	473
2007	100%	0%		322	341	473	322	341	473
2008	100%	0%		322	341	473	322	341	473
2009	100%	0%		322	341	473	322	341	473
2010	80%	20%		296	341	473	296	341	473
2011	60%	40%		271	341	473	271	341	473
2012	40%	60%		245	341	473	245	341	473
2013	20%	80%		220	341	473	220	341	473
2014	0%	100%		194	341	473	194	341	473
2015	0%	100%		194	341	473	194	341	473
2016	0%	100%		194	341	473	194	341	473
2017	0%	100%		194	341	473	194	341	473
2018	0%	100%		194	341	473	194	341	473
2019	0%	100%		194	341	473	194	341	473
2020	0%	100%		194	341	473	194	341	473

Appendix A: Sales Mix Summary
Scenario 1 = LEV 1 Transition to Tier 2 All States

PC + LDT1 (0 - 3,750 LVW)

MY	Tier 1	TLEV I	LEV I	ULEV I	Tier 2 - 7	Tier 2 - 5	Tier 2 - 3	Tier 2 - 1
NMOG Exh. Std.	0.250	0.125	0.075	0.040	0.090	0.090	0.055	0.000
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.95	0.00
1994	100%							
1995	85%	15%						
1996	80%	20%						
1997	65%	28%	5%	2%				
1998	36%	40%	18%	6%				
1999	13%	35%	46%	6%				
2000			94%	6%				
2001			85%	15%				
2002			80%	20%				
2003			64%	37%				
2004			30%	45%	1%	21%	3%	
2005			13%	37%	3%	43%	5%	
2006			5%	20%	4%	64%	8%	
2007					5%	85%	10%	
2008					5%	85%	10%	
2009					5%	85%	10%	
2010					5%	85%	10%	
2011					5%	85%	10%	
2012					5%	85%	10%	
2013					5%	85%	10%	
2014					5%	85%	10%	
2015					5%	85%	10%	
2016					5%	85%	10%	
2017					5%	85%	10%	
2018					5%	85%	10%	
2019					5%	85%	10%	
2020					5%	85%	10%	

NMOG Exhaust Fleet Avg
0.250
0.231
0.225
0.202
0.156
0.113
0.073
0.070
0.068
0.062
0.062
0.068
0.077
0.087
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Appendix A: Sales Mix Summary

Scenario 1 = LEV I Transition to Tier 2 **All States**

LDT2 (3,751 - 5,750 LVW)

MY	Tier 1	TLEV I	LEV I	ULEV I	Tier 2 - 7	Tier 2 - 5	Tier 2 - 3	Tier 2 - 1	NMOG Exhaust Fleet Avg
NMOG Exh. Std.	0.320	0.160	0.100	0.050	0.090	0.090	0.055	0.000	
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.95	0.00	
1994	100%								0.320
1995	85%	15%							0.296
1996	80%	20%							0.288
1997	65%	28%	7%						0.260
1998	37%	40%	23%						0.205
1999	14%	35%	49%	2%					0.151
2000			98%	2%					0.099
2001			95%	5%					0.098
2002			90%	10%					0.095
2003			85%	15%					0.093
2004			68%	7%	1%	21%	3%		0.093
2005			43%	7%	3%	43%	5%		0.090
2006			15%	10%	4%	64%	8%		0.085
2007					5%	85%	10%		0.087
2008					5%	85%	10%		0.087
2009					5%	85%	10%		0.087
2010					5%	85%	10%		0.087
2011					5%	85%	10%		0.087
2012					5%	85%	10%		0.087
2013					5%	85%	10%		0.087
2014					5%	85%	10%		0.087
2015					5%	85%	10%		0.087
2016					5%	85%	10%		0.087
2017					5%	85%	10%		0.087
2018					5%	85%	10%		0.087
2019					5%	85%	10%		0.087
2020					5%	85%	10%		0.087

Appendix A: Sales Mix Summary

Scenario 2 = LEV II with 2% ZEV, 2% ATPZEV, 6% PZEV **Massachusetts and Vermont**

PC + LDT1 (0 - 3,750 LVW)

	Group 1				Group 2		Group 3		Group 4		NMOG Exhaust	
Model Year	Tier 1	TLEV I	LEV I	ULEV I	LEV II	ULEV II	PZEV	ATPZEV	ZEV - FF	ZEV - CEV	Fleet Avg	Target
NMOG Exh. Std.	0.250	0.125	0.075	0.040	0.075	0.040	0.010	0.010	0.000	0.000		
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.50	0.50	0.35	0.35		
1994	100%										0.250	0.250
1995	85%	15%									0.231	0.231
1996	80%	20%									0.225	0.225
1997	65%	28%	5%	2%							0.202	0.202
1998	36%	40%	18%	6%							0.156	0.157
1999	13%	35%	46%	6%							0.113	0.113
2000			94%	6%							0.073	0.073
2001			85%	15%							0.070	0.070
2002			80%	20%							0.068	0.068
2003			63%	37%							0.062	0.062
2004			55%	20%	8%		17%				0.057	0.053
2005			35%	15%	23%		27%	1%			0.052	0.049
2006			25%		21%	12%	40%	2%	0.2%		0.043	0.046
2007					37%	15%	44%	3%	0.5%		0.039	0.043
2008					39%	10%	47%	4%	0.6%		0.038	0.040
2009					33%	10%	51%	5%	0.8%		0.034	0.038
2010					30%	10%	54%	5%	0.9%		0.032	0.035
2011					32%	5%	57%	6%	1.0%		0.032	0.035
2012					31%		61%	7%	1.3%		0.030	0.035
2013					31%		61%	7%	1.3%		0.030	0.035
2014					31%		61%	7%	1.3%		0.030	0.035
2015					24%		64%	10%	1.8%		0.026	0.035
2016					24%		64%	10%	1.8%		0.026	0.035
2017					24%		64%	10%	1.8%		0.026	0.035
2018					18%		68%	12%	2.2%		0.021	0.035
2019					18%		68%	12%	2.2%		0.021	0.035
2020					18%		68%	12%	2.2%		0.021	0.035

Appendix A: Sales Mix Summary

Scenario 3 = LEV II with 2% ZEV, 4% ATPZEV, 4% PZEV

Massachusetts and Vermont

PC + LDT1 (0 - 3,750 LVW)

	Group 1				Group 2		Group 3		Group 4		NMOG Exhaust	
Model Year	**Tier 1**	**TLEV I**	**LEV I**	**ULEV I**	**LEV II**	**ULEV II**	**PZEV**	**ATPZEV**	**ZEV - FF**	**ZEV - CEV**	**Fleet Avg**	**Target**
NMOG Exh. Std.	0.250	0.125	0.075	0.040	0.075	0.040	0.010	0.010	0.000	0.000		
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.50	0.50	0.35	0.35		
1994	100%										0.250	0.250
1995	85%	15%									0.231	0.231
1996	80%	20%									0.225	0.225
1997	65%	28%	5%	2%							0.202	0.202
1998	36%	40%	18%	6%							0.156	0.157
1999	13%	35%	46%	6%							0.113	0.113
2000			94%	6%							0.073	0.073
2001			85%	15%							0.070	0.070
2002			80%	20%							0.068	0.068
2003			63%	37%							0.062	0.062
2004			50%	25%	8%		17%				0.055	0.053
2005			35%	15%	18%	5%	27%	1%			0.050	0.049
2006			25%		23%	10%	40%	2%	0.2%		0.044	0.046
2007					44%	12%	39%	5%	0.5%		0.042	0.043
2008					37%	18%	36%	7%	0.6%		0.040	0.040
2009					38%	12%	40%	9%	0.8%		0.038	0.038
2010					32%	15%	42%	10%	0.9%		0.035	0.035
2011					35%	10%	44%	10%	1.0%		0.035	0.035
2012					39%		48%	12%	1.3%		0.035	0.035
2013					39%		48%	12%	1.3%		0.035	0.035
2014					39%		48%	12%	1.3%		0.035	0.035
2015					32%		51%	14%	1.8%		0.031	0.035
2016					32%		51%	14%	1.8%		0.031	0.035
2017					32%		51%	14%	1.8%		0.031	0.035
2018					26%		55%	17%	2.2%		0.027	0.035
2019					26%		55%	17%	2.2%		0.027	0.035
2020					26%		55%	17%	2.2%		0.027	0.035

Scenario 4 = LEV II with 10% FFEV ZEV **Massachusetts and Vermont**

PC + LDT1 (0 - 3,750 LVW)

	Group 1				Group 2		Group 3		Group 4			
Model Year	Tier 1	TLEV I	LEV I	ULEV I	LEV II	ULEV II	PZEV	ATPZEV	ZEV - FF	ZEV - CEV		
NMOG Exh. Std.	0.250	0.125	0.075	0.040	0.075	0.040	0.010	0.010	0.000	0.000	NMOG Exhaust	
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.50	0.50	0.35	0.35	Fleet Avg	Target
1994	100%										0.250	0.250
1995	85%	15%									0.231	0.231
1996	80%	20%									0.225	0.225
1997	65%	28%	5%	2%							0.202	0.202
1998	36%	40%	18%	6%							0.156	0.157
1999	13%	35%	46%	6%							0.113	0.113
2000			94%	6%							0.073	0.073
2001			85%	15%							0.070	0.070
2002			80%	20%							0.068	0.068
2003			63%	37%							0.062	0.062
2004			45%	30%	11%		14%		0%		0.055	0.053
2005			20%	30%	30%		20%		0%		0.051	0.049
2006			5%	20%	31%	15%	28%		0.9%		0.044	0.046
2007					28%	45%	25%		2.0%		0.041	0.043
2008					16%	65%	16%		3.0%		0.040	0.040
2009					13%	65%	18%		3.6%		0.038	0.038
2010					7%	70%	19%		4.0%		0.035	0.035
2011					8%	68%	20%		4.2%		0.035	0.035
2012					11%	62%	22%		5.4%		0.035	0.035
2013					11%	62%	22%		5.4%		0.035	0.035
2014					11%	62%	22%		5.4%		0.035	0.035
2015					14%	54%	26%		6.3%		0.035	0.035
2016					14%	54%	26%		6.3%		0.035	0.035
2017					14%	54%	26%		6.3%		0.035	0.035
2018					19%	45%	29%		7.1%		0.035	0.035
2019					19%	45%	29%		7.1%		0.035	0.035
2020					19%	45%	29%		7.1%		0.035	0.035

Appendix A: Sales Mix Summary

Scenario 5 = LEV II with 5% FFEV, 5% CEV

Massachusetts and Vermont

PC + LDT1 (0 - 3,750 LVW)

	Group 1				Group 2		Group 3		Group 4			
Model Year	**Tier 1**	**TLEV I**	**LEV I**	**ULEV I**	**LEV II**	**ULEV II**	**PZEV**	**ATPZEV**	**ZEV - FF**	**ZEV - CEV**	**NMOG Exhaust Fleet Avg**	**NMOG Exhaust Target**
NMOG Exh. Std.	0.250	0.125	0.075	0.040	0.075	0.040	0.010	0.010	0.000	0.000		
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.50	0.50	0.35	0.35		
1994	100%										0.250	0.250
1995	85%	15%									0.231	0.231
1996	80%	20%									0.225	0.225
1997	65%	28%	5%	2%							0.202	0.202
1998	36%	40%	18%	6%							0.156	0.157
1999	13%	35%	46%	6%							0.113	0.113
2000			94%	6%							0.073	0.073
2001			85%	15%							0.070	0.070
2002			80%	20%							0.068	0.068
2003			63%	37%							0.062	0.062
2004			50%	25%	1%	10%	14%		0%	0%	0.053	0.053
2005			30%	20%	14%	15%	20%		0%	1%	0.049	0.049
2006			15%	10%	27%	18%	28%		0.5%	1.0%	0.046	0.046
2007					30%	42%	25%		1.0%	1.9%	0.042	0.043
2008					19%	60%	16%		1.5%	3.7%	0.040	0.040
2009					16%	60%	18%		1.8%	4.3%	0.038	0.038
2010					10%	65%	19%		2.0%	4.5%	0.035	0.035
2011					10%	64%	20%		2.1%	4.8%	0.035	0.035
2012					14%	56%	22%		2.7%	5.6%	0.035	0.035
2013					14%	56%	22%		2.7%	5.6%	0.035	0.035
2014					14%	56%	22%		2.7%	5.6%	0.035	0.035
2015					19%	46%	26%		3.1%	6.5%	0.035	0.035
2016					19%	46%	26%		3.1%	6.5%	0.035	0.035
2017					19%	46%	26%		3.1%	6.5%	0.035	0.035
2018					24%	36%	29%		3.6%	7.4%	0.035	0.035
2019					24%	36%	29%		3.6%	7.4%	0.035	0.035
2020					24%	36%	29%		3.6%	7.4%	0.035	0.035

Scenario 2 = LEV II with 2% ZEV, 2% ATPZEV, 6% PZEV

New York State

PC + LDT1 (0 - 3,750 LVW)

	Group 1				Group 2		Group 3		Group 4			
Model Year	**Tier 1**	**TLEV I**	**LEV I**	**ULEV I**	**LEV II**	**ULEV II**	**PZEV**	**ATPZEV**	**ZEV - FF**	**ZEV - CEV**	**NMOG Exhaust**	
NMOG Exh. Std.	0.250	0.125	0.075	0.040	0.075	0.040	0.010	0.010	0.000	0.000		
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.50	0.50	0.35	0.35	**Fleet Avg**	**Target**
1994	100%										0.250	0.250
1995	85%	15%									0.231	0.231
1996	80%	20%									0.225	0.225
1997	65%	28%	5%	2%							0.202	0.202
1998	36%	40%	18%	6%							0.156	0.157
1999	13%	35%	46%	6%							0.113	0.113
2000			94%	6%							0.073	0.073
2001			85%	15%							0.070	0.070
2002			80%	20%							0.068	0.068
2003			63%	37%							0.062	0.062
2004			55%	20%	8%		17%				0.057	0.053
2005			35%	15%	3%	20%	26%	1%			0.045	0.049
2006			25%		22%	18%	32%	2%	0.2%		0.046	0.046
2007					41%	20%	35%	3%	0.5%		0.043	0.043
2008					36%	22%	38%	4%	0.6%		0.040	0.040
2009					31%	22%	41%	5%	0.8%		0.037	0.038
2010					28%	22%	44%	5%	0.9%		0.035	0.035
2011					31%	16%	46%	5%	0.9%		0.035	0.035
2012					34%	8%	50%	7%	1.3%		0.035	0.035
2013					34%	8%	50%	7%	1.3%		0.035	0.035
2014					34%	8%	50%	7%	1.3%		0.035	0.035
2015					37%		52%	9%	1.7%		0.034	0.035
2016					37%		52%	9%	1.7%		0.034	0.035
2017					37%		52%	9%	1.7%		0.034	0.035
2018					33%		54%	11%	2.1%		0.031	0.035
2019					33%		54%	11%	2.1%		0.031	0.035
2020					33%		54%	11%	2.1%		0.031	0.035

Appendix A: Sales Mix Summary

Scenario 3 = LEV II with 2% ZEV, 4% ATPZEV, 4% PZEV **New York State**

PC + LDT1 (0 - 3,750 LVW)

	Group 1				Group 2		Group 3		Group 4			
Model Year	Tier 1	TLEV I	LEV I	ULEV I	LEV II	ULEV II	PZEV	ATPZEV	ZEV - FF	ZEV - CEV		
NMOG Exh. Std.	0.250	0.125	0.075	0.040	0.075	0.040	0.010	0.010	0.000	0.000	NMOG Exhaust	
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.50	0.50	0.35	0.35	Fleet Avg	Target
1994	100%										0.250	0.250
1995	85%	15%									0.231	0.231
1996	80%	20%									0.225	0.225
1997	65%	28%	5%	2%							0.202	0.202
1998	36%	40%	18%	6%							0.156	0.157
1999	13%	35%	46%	6%							0.113	0.113
2000			94%	6%							0.073	0.073
2001			85%	15%							0.070	0.070
2002			80%	20%							0.068	0.068
2003			63%	37%							0.062	0.062
2004			50%	25%	8%		17%				0.055	0.053
2005			35%	15%	8%	15%	26%	1%			0.050	0.049
2006			25%		22%	18%	32%	2%	0.2%		0.044	0.046
2007					39%	25%	31%	4%	0.5%		0.042	0.043
2008					32%	32%	28%	7%	0.6%		0.040	0.040
2009					28%	32%	31%	9%	0.8%		0.038	0.038
2010					22%	35%	33%	9%	0.9%		0.035	0.035
2011					25%	30%	35%	10%	0.9%		0.035	0.035
2012					28%	22%	37%	11%	1.3%		0.035	0.035
2013					28%	22%	37%	11%	1.3%		0.035	0.035
2014					28%	22%	37%	11%	1.3%		0.035	0.035
2015					33%	12%	39%	14%	1.7%		0.031	0.035
2016					33%	12%	39%	14%	1.7%		0.031	0.035
2017					33%	12%	39%	14%	1.7%		0.031	0.035
2018					36%	4%	42%	16%	2.1%		0.027	0.035
2019					36%	4%	42%	16%	2.1%		0.027	0.035
2020					36%	4%	42%	16%	2.1%		0.027	0.035

Appendix A: Sales Mix Summary

Scenario 4 = LEV II with 10% FFEV ZEV **New York State**

PC + LDT1 (0 - 3,750 LVW)

	Group 1				Group 2		Group 3		Group 4			
Model Year	Tier 1	TLEV I	LEV I	ULEV I	LEV II	ULEV II	PZEV	ATPZEV	ZEV - FF	ZEV - CEV		
NMOG Exh. Std.	0.250	0.125	0.075	0.040	0.075	0.040	0.010	0.010	0.000	0.000	NMOG Exhaust	
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.50	0.50	0.35	0.35	Fleet Avg	Target
1994	100%										0.250	0.250
1995	85%	15%									0.231	0.231
1996	80%	20%									0.225	0.225
1997	65%	28%	5%	2%							0.202	0.202
1998	36%	40%	18%	6%							0.156	0.157
1999	13%	35%	46%	6%							0.113	0.113
2000			94%	6%							0.073	0.073
2001			85%	15%							0.070	0.070
2002			80%	20%							0.068	0.068
2003			63%	37%							0.062	0.062
2004			45%	30%	3%	8%	14%		0%		0.053	0.053
2005			20%	30%	22%	8%	19%		0%		0.049	0.049
2006			5%	20%	31%	22%	21%		0.9%		0.046	0.046
2007					26%	55%	17%		2.0%		0.043	0.043
2008					11%	78%	8%		2.9%		0.040	0.040
2009					7%	80%	10%		3.4%		0.038	0.038
2010						86%	11%		3.8%		0.035	0.035
2011						85%	11%		4.0%		0.035	0.035
2012						82%	13%		5.1%		0.034	0.035
2013						82%	13%		5.1%		0.034	0.035
2014						82%	13%		5.1%		0.034	0.035
2015					4%	75%	15%		5.9%		0.035	0.035
2016					4%	75%	15%		5.9%		0.035	0.035
2017					4%	75%	15%		5.9%		0.035	0.035
2018					8%	68%	17%		6.8%		0.035	0.035
2019					8%	68%	17%		6.8%		0.035	0.035
2020					8%	68%	17%		6.8%		0.035	0.035

Appendix A: Sales Mix Summary

Scenario 5 = LEV II with 5% FFEV, 5% CEV **New York State**

PC + LDT1 (0 - 3,750 LVW)

Model Year	Group 1				Group 2		Group 3		Group 4		NMOG Exhaust	
	Tier 1	**TLEV I**	**LEV I**	**ULEV I**	**LEV II**	**ULEV II**	**PZEV**	**ATPZEV**	**ZEV - FF**	**ZEV - CEV**	**Fleet Avg**	**Target**
NMOG Exh. Std.	0.250	0.125	0.075	0.040	0.075	0.040	0.010	0.010	0.000	0.000		
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.50	0.50	0.35	0.35		
1994	100%										0.250	0.250
1995	85%	15%									0.231	0.231
1996	80%	20%									0.225	0.225
1997	65%	28%	5%	2%							0.202	0.202
1998	36%	40%	18%	6%							0.156	0.157
1999	13%	35%	46%	6%							0.113	0.113
2000			94%	6%							0.073	0.073
2001			85%	15%							0.070	0.070
2002			80%	20%							0.068	0.068
2003			63%	37%							0.062	0.062
2004			50%	25%	1%	10%	14%		0%	0%	0.054	0.053
2005			30%	20%	12%	18%	19%		0%	1%	0.049	0.049
2006			15%	10%	22%	30%	21%		0.5%	1.0%	0.046	0.046
2007					25%	55%	17%		1.0%	1.8%	0.043	0.043
2008					12%	75%	8%		1.4%	3.6%	0.040	0.040
2009					9%	75%	10%		1.7%	4.1%	0.038	0.038
2010					3%	80%	11%		1.9%	4.3%	0.035	0.035
2011					2%	80%	11%		2.0%	4.6%	0.035	0.035
2012					4%	75%	13%		2.5%	5.3%	0.035	0.035
2013					4%	75%	13%		2.5%	5.3%	0.035	0.035
2014					4%	75%	13%		2.5%	5.3%	0.035	0.035
2015					8%	68%	15%		3.0%	6.2%	0.035	0.035
2016					8%	68%	15%		3.0%	6.2%	0.035	0.035
2017					8%	68%	15%		3.0%	6.2%	0.035	0.035
2018					13%	60%	17%		3.4%	7.0%	0.035	0.035
2019					13%	60%	17%		3.4%	7.0%	0.035	0.035
2020					13%	60%	17%		3.4%	7.0%	0.035	0.035

Appendix A: Sales Mix Summary

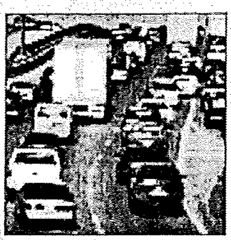
Scenarios 2 through 5 (LEV II) **All States**

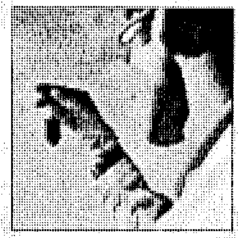
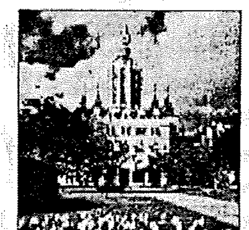
LDT2 (3,751 - 5,750 LVW)

Model Year	Group 1				Group 2		Group 3		Group 4			
	Tier 1	TLEV I	LEV I	ULEV I	LEV II	ULEV II	PZEV	ATPZEV	ZEV - FF	ZEV - CEV	NMOG Exhaust	
NMOG Exh. Std.	0.320	0.160	0.100	0.050	0.075	0.040	0.010	0.010	0.000	0.000	Fleet Avg	Target
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.65	0.65	0.50	0.50		
1994	100%										0.320	0.320
1995	85%	15%									0.296	0.295
1996	80%	20%									0.288	0.287
1997	65%	28%	7%								0.260	0.260
1998	37%	40%	23%								0.205	0.205
1999	14%	35%	49%	2%							0.151	0.150
2000			98%	2%							0.099	0.099
2001			95%	5%							0.098	0.098
2002			90%	10%							0.095	0.095
2003			85%	15%							0.093	0.093
2004			55%	20%	25%						0.084	0.085
2005			25%	25%	50%						0.075	0.076
2006			10%	15%	45%	30%					0.063	0.062
2007					40%	60%					0.054	0.055
2008					25%	75%					0.049	0.050
2009					20%	80%					0.047	0.047
2010					8%	92%					0.043	0.043
2011					8%	92%					0.043	0.043
2012					8%	92%					0.043	0.043
2013					8%	92%					0.043	0.043
2014					8%	92%					0.043	0.043
2015					8%	92%					0.043	0.043
2016					8%	92%					0.043	0.043
2017					8%	92%					0.043	0.043
2018					8%	92%					0.043	0.043
2019					8%	92%					0.043	0.043
2020					8%	92%					0.043	0.043

The Drive for Cleaner Air in Connecticut:

The Benefits of Adopting the California Low-Emission Vehicle Standard for Cars and Light Duty Trucks



Connecticut Fund for the Environment

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Connecticut Fund for the Environment is a statewide, nonprofit organization that uses science, law, and public education to protect Connecticut's natural resources. Connecticut Fund for the Environment was founded in 1978 and has a membership base of about 3,700 individuals and a 14-member professional staff of attorneys, researchers, and organizers.

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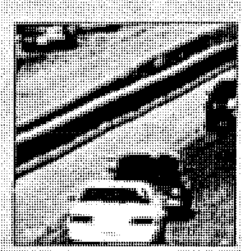
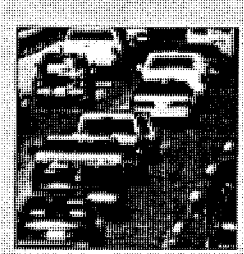

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Introduction

Connecticut residents suffer from poor air quality and its associated health effects, and motor vehicles are among the biggest contributors to air pollution. When it comes to auto emission standards, states have a choice: they can remain by default in the national program (currently the National Low-Emission Vehicle program, phasing into the Tier 2 program from 2004-2006) with its *minimum* standards, or they can legislatively or administratively choose to adopt the *stricter* standards California has created (currently called LEV II for Low-Emission Vehicles II program). Under the federal Clean Air Act, a state must either participate in the national vehicle emissions program or adopt California's low-emission vehicle standards.[1]

Connecticut now has the opportunity to join the neighboring states of Massachusetts and New York[a] in adopting the stricter LEV II program, which would better protect public health. If LEV II is adopted in Connecticut in 2004, it could take effect beginning with model year 2007.[2]

Because a substantial portion of the state's hazardous air pollution comes from cars and light duty trucks on Connecticut's highways, reducing harmful emissions from transportation sources will significantly improve the health and quality of life of Connecticut citizens.

Air Toxics and Criteria Pollutants[b]

While the air in Connecticut has improved over the last several years, it is still among the most polluted in the nation. The average Connecticut resident's added cancer risk from hazardous air pollution is the ninth highest risk average in the country.[3] The average Connecticut resident's cancer risk from hazardous air pollution is approximately 850 times higher than the Clean Air Act goal.[c]

Highway mobile sources are responsible for more than 40 percent of air toxic[d] emissions in Connecticut.[4] Motor vehicles are also major sources of criteria pollutants. Highway mobile sources are responsible for nearly half of nitrogen oxide (NOx) emissions and nearly a third of volatile organic compound emissions (VOCs) in Connecticut.[e]

Cars, diesel vehicles, and other mobile sources create more than 80 percent of cancer and non-cancer health risks from air pollution in Connecticut.[5] These health risks range from cancer and heart attacks to asthma attacks and days lost from school.

General air quality improvements have been made since the 1970s to reduce criteria pollutant levels, but even greater efforts to control pollution from vehicles are needed to address health risks. The health and environmental impacts of vehicle pollution, the trend toward increasing vehicle travel, the continuing difficulty in meeting national air quality standards for ozone, and the issue of climate change all contribute to the need for additional steps to reduce vehicle emissions.

Greenhouse Gases

Connecticut's transportation sector produces the single largest and fastest growing portion of the state's greenhouse gas emissions. The state transportation sector's share of CO_2 and other greenhouse emissions grew to 45 percent of all-source emissions in 2000, up from 35 percent in 1990. Of the various transportation modes, passenger cars and light duty trucks are the largest sources of transportation greenhouse gas emissions (GHG), accounting for 61 percent of transportation emissions.[6]

Global warming carries potentially serious health and ecological impacts for the northeast in general and Connecticut in particular. As the temperature rises and air quality diminishes, respiratory disease and heat-related problems increase.[7]

Numerical source references are listed on pages 37 and 38.

a Maine and Vermont are also LEV II states, but they have not implemented the ZEV component of the program. Vermont is expected to fully adopt the ZEV program in the coming year.

b Criteria pollutants include carbon monoxide, ground-level ozone, lead, nitrogen oxides, particulate matter, and sulfur dioxide. Air quality standards implemented over the last 30 years have largely focused on meeting health-based ambient air quality standards for these six pollutants.

c Scorecard reports use electronically available EPA data ranging from 1996-2000 to assess hazardous air and criteria pollutant exposures. As Environmental Defense states, all risk statements are based on a screening-level assessment of potential health risks and are subject to important uncertainties. As such, the risk estimates are useful for ranking purposes, but not necessarily predictive of any actual individual's risk of getting a particular disease. Environmental Defense Scorecard, available at www.scorecard.org.

d Statistic includes 32 air toxics of greatest public health concern in urban areas (as determined by US EPA in their National Air Toxics Assessment) as well as diesel.

e Data is from Connecticut Department of Environmental Protection 1999 Ozone and Carbon Monoxide State Implementation Plan (SIP) emission inventories for all non-attainment areas within the state of Connecticut. These figures are based on typical ozone summer days, and do not include biogenic sources (corn, grasses, and trees).

Report Methodology

This report examines the three major categories of pollutants that come from cars and light duty trucks: air toxics, criteria pollutants, and greenhouse gases. Emissions of these pollutants would be significantly and effectively reduced with the simple, cost-effective adoption of the California Low-Emission Vehicle Program (LEV II). This report demonstrates that reducing pollutant emissions in each of these categories is an achievable goal that will have a substantial benefit for the health of Connecticut citizens and the future of the state's natural environment.

In support of our analysis, Cambridge Systematics[f] used U.S. Environmental Protection Agency's Mobile 6 software[g] and Argonne National Laboratory's GREET model[h] to model the emissions benefits of the LEV II program over federal Tier 2, the default program in place in Connecticut. We quantified emissions reductions and, to the extent possible, health benefits, for each pollutant category.

Our analysis centered on four air toxics highly recognized as hazardous components of vehicle exhaust: acetaldehyde, benzene, 1,3-butadiene, and formaldehyde. These four air toxics represent a disproportionate fraction of health risks from auto emissions, particularly cancer and respiratory irritant risk, as discussed in more detail in the "Air Toxic Problem in Connecticut" section of this report. While other pollutants present in motor vehicle emissions contribute to adverse health outcomes, the four air toxics we chose can be measured with a relatively high degree of toxicological precision and are responsible for most of the light duty automobile emissions risk.[i] To quantify non-cancer benefits, we calculated the reduction in respiratory irritant risk from cumulative exposure to eight air toxics (nearly all of the risk was driven by the four air toxics we modeled as well as their breakdown products). Again, these air toxics and associated health endpoints describe some of the benefits LEV II could bring from reduced passenger car and light duty truck emissions, but the calculated benefits in this report are likely to be substantially less than actual benefits.

We also modeled emissions reductions for two smog precursors: nitrogen oxides (NOx) and volatile organic compounds (VOCs). Reductions in particulate matter (PM), including diesel particulate matter, were not modeled because there is a great deal of uncertainty about the portion of light duty vehicles that might run on diesel fuel in the years to come (airborne PM comes largely from diesel vehicles). We include only a qualitative discussion of criteria pollutant benefits due to complexities in making more quantitative benefit estimates for ozone, its precursors, and particulate matter, as described later in this report.

Finally, we modeled reductions in greenhouse gases for Tier 2, the baseline LEV II program, as well as two LEV II implementation scenarios, since the GHG reductions vary depending on how the "zero-emission" vehicle (ZEV) mandate of the LEV II program is implemented. The ZEV feature of the program refers to the inclusion of a variety of advanced automobile technologies such as hybrid-electric vehicles, super low-emitting gasoline vehicles and hydrogen fuel cell vehicles in vehicle fleets. The GHG benefits are likely to increase given more aggressive adoption of advanced automobile technologies. Connecticut could also take advantage of stricter California GHG requirements expected to be phased in over time, but no other benefits were modeled in this analysis.

f Cambridge Systematics is an independent consulting firm with more than 20 years of experience in transportation and air quality planning initiatives.

g Mobile 6 is used by EPA in evaluating control strategies for highway mobile sources, by states and other planning agencies in the development of emission inventories and control strategies for State Implementation Plans under the Clean Air Act, and in the development of environmental impact statements.

h The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model was developed by Argonne National Laboratory for the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE).

i It should be noted that polyaromatic hydrocarbons (PAHs) are also emitted in motor vehicle exhaust, but are not quantified in this report. They were excluded because they are a mixture of compounds that are difficult to measure precisely and automobiles are not a major source of PAH emissions. Also note that acrolein, the major contributor to respiratory irritant risk, was not modeled by Mobile 6. This compound is one of 1,3-butadiene's breakdown products, and is extremely difficult to measure precisely.

Auto Emissions Standards: A Comparison of the National Program and LEV II

California was the first state to address the negative effects of vehicle emissions, acting early to develop a vehicle emissions program. As a result, federal law allows the state to continue to develop and implement its own vehicle emissions standards.

In 1990, California adopted its low-emission vehicle (LEV I) and Zero-Emission Vehicle (ZEV) standards to meet health-based air quality goals. These standards, which were much lower than the federal standards in place at the time, allowed manufacturers to certify vehicles to a series of increasingly more stringent emissions categories or bins, provided that their fleets met overall average standards.

Both California and the federal government adopted even tougher new standards in 1999 to limit air pollution emissions from a wider range of motor vehicles beginning in model year 2004. The stricter California program is called LEV II; the federal program, Tier 2.

A Comparison of Tier 2 and LEV II

While Tier 2 and LEV II have several fundamental differences, they are similar programs in three main respects. First, they both utilize the bin system developed by California with the 1990 LEV I standards. That is, vehicle manufacturers can certify particular vehicles into any of the emissions bins – as long as their fleet-average emissions meet the program standards. Over time, manufacturers will need to certify a greater proportion of their cars to cleaner bins to meet declining fleet averages. Also, both programs eliminate the SUV and minivan loophole that exempted many light trucks from the stricter emissions standards in place for passenger cars.[8] Third, both established tighter emissions levels for vehicles regardless of whether they use gasoline or diesel fuel. The following paragraphs detail the differences between the two programs.

The four categories or bins of emissions standards to which automobile manufacturers can certify vehicles under LEV II include LEV (low-emission vehicles), ULEV (ultra low-emission vehicles), SULEV (super ultra low-emission vehicles), and ZEV (zero emission vehicles). For 2003 model year passenger cars, SULEV vehicles are 90 percent cleaner than the average new 2003 model year car and ULEV vehicles are 50 percent cleaner than average. For 2003 model year trucks, vans, and SUVs, SULEVs are 70 percent cleaner than the average similar weight vehicle and ULEVs are 50 percent cleaner than the average similar weight new vehicle.

Emission Bin Structure and Standards. The Tier 2 program requires manufacturers to meet a fleet-wide average for NOx rather than non-methane organic gas (NMOG). While Tier 2 also regulates NMOG, the Tier 2 bins are not structured so as to guarantee as great a reduction in NMOG as LEV II. The LEV II program requires manufacturers to achieve a declining fleet average for NMOG, while the Tier 2 standard remains constant over time.

Evaporative Emissions. LEV II requires greater reductions in the key area of evaporative emissions than Tier 2. Evaporative emissions are very important in the generation of hazardous air pollutants because they are responsible for about half of the hydrocarbon emissions from current motor vehicles. The two programs also have different hot soak and diurnal emissions requirements. See "Evaporative Emissions" in the Appendix A section, and "Calculation of Air Toxics, VOC & NOx Emissions" for more information on these evaporative emissions standards.

Advanced Technology. Only LEV II requires the penetration of zero emission vehicles into vehicle fleets. Under the ZEV requirement, 10 percent of the vehicles sold must be Advanced Technology Vehicles until 2009, with the credit requirement increasing up to 16 percent by 2018. Not all of the vehicles under the ZEV requirement must have zero tailpipe and evaporative emissions; LEV II creates partial Zero-Emission Vehicle credits for vehicles that achieve near zero emissions, such as conventional vehicles that meet certain emissions, durability,

Evaporative emissions *are those emissions that escape from the fuel tank or fuel system.*

Hot soak emissions *are releases that occur when a car is cooling off following a trip. These account for about 38 percent of vehicle emissions.*

Diurnal emissions *take place due to "breathing" of the gas tank caused by changes in ambient temperature. These account for about 10 percent of vehicle emissions.*

ZEV: Zero Emission Vehicle; includes full-function electric vehicles or hydrogen fuel cell vehicles.

PZEV: Partial ZEV; conventional gasoline engine vehicles with advanced emissions control technology, such as the 2003 Nissan Sentra CA.

ATV: Advanced Technology Vehicles.

AT PZEV: Advanced Technology PZEV; gasoline-electric hybrids, similar to the 2003 Honda Insight or Toyota Prius.

and warranty requirements (called partial ZEVs or PZEVs). ZEV regulations were recently amended to allow greater flexibility in meeting the ZEV credit requirements with the alternative compliance path, as described below.

The current ZEV program allows manufacturers to follow one of two compliance paths: the conventional path, which maintains the two-percent ZEV, two-percent AT PZEV (advanced technology PZEV), and six-percent PZEV requirement; or the alternative compliance path, which allows manufacturers to meet the ZEV mandate with AT PZEVs and PZEVs. (See "Program Structure and Sales Mix" in Appendix A for more information.)

Diesel. LEV II ensures a cleaner mix of vehicles on the road by denying automakers the flexibility allowed under Tier 2 to produce diesel-fueled vehicles. This is because Tier 2 has more lenient particulate matter standards, allowing diesel vehicles to release about twice as much particulate matter as would be possible under LEV II.

Scenario Assumptions

In this analysis, we compare the car and light duty truck emissions of air toxics, criteria pollutants, and greenhouse gases in calendar years 2003, 2015, and 2025. We chose these years in order to assess the long-term impacts of LEV II and Tier 2.

- Tier 2. This scenario is consistent with the default federal program, with transition from the state's current National Low-Emission Vehicles (NLEV) program to Federal Tier 2 in 2004 through 2006, consistent with the national Tier 2 phase-in schedule. By default, this is the program that is in place in Connecticut.
- LEV II. This scenario presents the baseline LEV II program, in which minimally achievable reductions from LEV II implementation are attained, with automakers meeting the minimum ZEV regulatory requirements of the program.[J] This is the scenario for which we report emissions reductions results for air toxics and criteria pollutants. In the greenhouse gas section of this report we also discuss two variations on the ZEV component of LEV II, in order to more fully describe the range of benefits that might be achieved through LEV II.

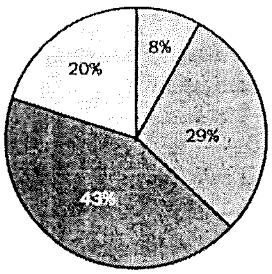
Our assumptions differ slightly from EPA-recommended methodology for modeling air quality reductions using the U.S. Environmental Protection Agency's Mobile 6.2. software (see page 10). Key areas of difference are in the distribution of vehicles sales by bin and the treatment of zero-evaporative vehicle emissions. See Appendix A ("Differences Compared to the EPA-Recommended LEV II Analysis Methodology") for a more detailed discussion of these differences and implications for comparing these results with other analyses.

J In this scenario, manufacturers are assumed to follow the conventional compliance path. As a result, automakers would need to meet the two percent ZEV requirement in early years with battery-electric vehicles. It is more likely, however, that automakers will choose to follow the alternative compliance path, in which pure ZEVs will not be introduced in the fleet until 2012. We chose to assume the conventional compliance path because it is associated with the most conservative estimate of air pollution reduction benefits; as a result, we provide an underestimate of the potential air pollution and health benefits from LEV II.

The Air Toxics Problem in Connecticut

Cars, trucks, buses, and other transportation sources are responsible for the majority of hazardous air pollutant emissions in Connecticut. Other emissions sources, in order of relative contribution, are area sources (small stationary sources such as dry cleaners and gas stations), off-highway sources (trains, construction vehicles, and ships), and point sources (large, stationary facilities such as electrical utility plants).

Figure 1
Source Contribution to
33 Air Toxics in Connecticut



- Stationary Point Sources 8%
- Stationary Area and Other Sources 29%
- Highway Mobile Sources 43%
- Off-Highway Mobile Sources 20%

Highway mobile sources are responsible for more than 40 percent of air toxic[k] emissions in Connecticut.[3] Because motor vehicles are major contributors to air toxic emissions in the state, the overall reduction in health risk from a fractional decrease in emissions would be significant.

This report examines the modeled reductions in acetaldehyde, benzene, 1,3-butadiene, and formaldehyde – four substances that represent a disproportionate portion of the health risks from motor vehicles, from adopting LEV II as compared to the national default Tier 2.

As illustrated in Table 1 below, light duty vehicles – the vehicle classes that would be subject to the California standards – are responsible for a significant portion of the average ambient concentrations of these pollutants across Connecticut census tracts.[l] While it is important to note that background levels due to pollutant transport have a significant impact on ambient levels of benzene and formaldehyde, light duty vehicles have a considerable impact on Connecticut air toxic pollution over all.

Table 1. Connecticut Sources of Motor Vehicle-Associated Air Toxics

	Primary Sources	Source Contribution to Average Ambient Concentration			
		Light Duty Vehicles[m]	All Other Mobile[n]	Back-ground	Major, Area and Other
Acetaldehyde	Fuel combustion processes	60%	34%	0%	6%
Benzene	Gasoline fugitive emissions, gas motor vehicle exhaust	24%	35%	38%	3%
1,3-Butadiene	Incomplete combustion of gas and diesel fuels	75%	20%	0%	5%
Formaldehyde	Vehicle exhaust; photochemical oxidation of reactive gases	28%	44%	22%	6%

k Statistic includes 32 air toxics of greatest public health concern in urban areas (as determined by US EPA in their National Air Toxics Assessment) as well as diesel. The list was developed with an emphasis on carcinogenicity, mutagenicity, and teratogenicity. See Appendix B for a complete list of these air toxics.
l US EPA air toxics inventory data from 1996, compiled in the National Air Toxics Assessment.
m These percentages were calculated using national average contributions of light duty vehicle emissions to total onroad vehicle emissions. Data from US EPA, *The Projection of Mobile Source Air Toxics from 1996 to 2007: Emissions and Concentrations*. EPA420-R-01-038. August 2001.
n "All Other Mobile" includes off-road mobile sources as well as heavy duty on-road mobile sources.

Health Impacts

Respiratory irritants exacerbate existing lung conditions, such as emphysema and COPD (chronic obstructive pulmonary disease, a serious chronic lung condition), and are known asthma triggers.

Air pollution affects the quality of life for Connecticut citizens. According to Environmental Defense's Scorecard, cars, diesel vehicles, and other motor vehicles create more than 80 percent of the health risks from air pollution in Connecticut.[10]

Epidemiological studies have linked air pollutants with increased asthma symptoms, days lost from school and work, emergency room and hospital admissions, and mortality. In addition, many of the hazardous air pollutants identified in the Clean Air Act are known or suspected to cause cancer. The health effects resulting from exposure to each of the four pollutants that are the focus of this study are:[11]

- Acetaldehyde, a probable human carcinogen that can lead to eye, skin and respiratory tract irritation in acute exposures. It is also known to intensify asthma.
- Benzene, a known human carcinogen that is also associated with a number of central nervous system symptoms, reproductive effects, and eye and respiratory tract irritation.
- 1,3-Butadiene, a probable human carcinogen whose vapors can be mildly irritating to the eyes and mucous membranes. It is also associated with cardiovascular effects and its vapors may cause neurological effects at very high levels. Acrolein, a highly irritating and very toxic pollutant, is one of 1,3-butadiene's breakdown products.
- Formaldehyde, a probable human carcinogen that is highly irritating to the eye and respiratory tract. Acute effects include nausea, headaches, and difficulty breathing; formaldehyde can also exacerbate asthma.

Nationally, benzene, 1,3-butadiene, formaldehyde, and acetaldehyde are responsible for nearly all of the cumulative lifetime cancer risk from highway mobile sources.[o] Given that the highway mobile source sector is among the most important contributors to cancer risk from breathing outdoor air, these four chemicals are very important drivers of overall cancer risk from air pollution.[p] In fact, there were at least 10 million Americans living in census tracts where the typical risk from benzene and formaldehyde exceeded 10 in a million in 1996, and more than 100,000 people living in census tracts where the typical risk from 1,3-butadiene exceeded 10 in a million.[q]

Nearly the entire U.S. population lived in census tracts in which they were at risk from respiratory irritant exposure in 1996. Acetaldehyde, formaldehyde, 1,3-butadiene, and acrolein accounted for nearly all of the respiratory irritant risk.[r] The onroad sector is the source sector responsible for the largest contribution to the respiratory hazard index.[s]

See Appendix B for more detailed information about the health risks associated with these pollutants, and other important toxic air pollutants.

o See (http://www.epa.gov/ttn/atw/nata/rcharts/figure03.pdf) for the distribution of lifetime cancer risk for the US population, based on 1996 exposure to on-road mobile sources. Diesel was not included in this assessment.

p See (http://www.epa.gov/ttn/atw/nata/rcharts/figure25.pdf) for the distribution of lifetime cancer risk for the US population, based on 1996 exposure to 29 carcinogenic air pollutants from various source sectors.

q See (http://www.epa.gov/ttn/atw/nata/rcharts/figure15.pdf) for the population whose 1996 exposure exceeded set cancer risk levels based on road mobile sources.

r See (http://www.epa.gov/ttn/atw/nata/rcharts/figure21.pdf) for the population whose 1996 exposure exceeded set hazard quotient levels based on onroad mobile sources.

s See (http://www.epa.gov/ttn/atw/nata/rcharts/figure26.pdf) for the distribution of respiratory hazard index for the US population, based on 1996 exposure to 8 respiratory irritant air pollutants from various source sectors.

Air Toxic Reductions as a Result of LEV II in Comparison with Tier 2

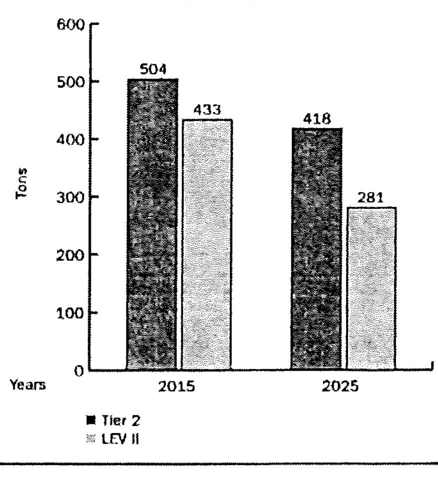
Methodology

We used the U.S. Environmental Protection Agency's Mobile 6.2 software to compare Tier 2 and LEV II. This program calculates average in-use emission factors for each category of vehicle for any calendar year and under various conditions affecting emission levels (e.g., ambient temperatures, average traffic speed, gasoline volatility.)[12] The model gives emission factors expressed as grams per vehicle mile traveled (g/mi) that is combined with total vehicle miles traveled (VMT) to develop emission inventories from highway vehicles. Emission factor changes reflect variables such as fleet turnover, reduced evaporative emissions, and reduced hot soak emissions. Vehicle-miles of travel (VMT) estimates were obtained from the Connecticut Department of Transportation (ConnDOT) for the years 2003, 2015, and 2025 and compared to federally reported trends. Based on the VMT fractions assumed in the DEP's Mobile 6.2 input files for year 2007, we allocated total VMT by vehicle class.[t] See the "Calculation of Air Toxics, VOC and NOx Emissions" in Appendix A for VMT estimates by year and vehicle type as well as a more detailed discussion of the inputs and assumptions used in our analysis.

Findings

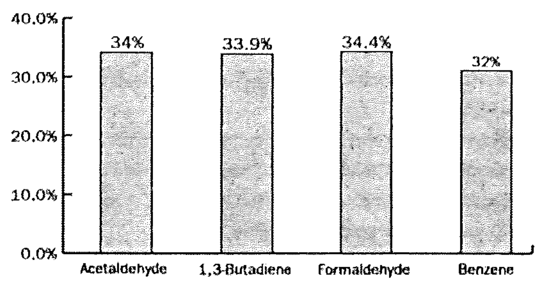
Emissions from motor vehicles would be significantly less under LEV II than Tier 2 in 2015 and 2025 (see Figure 2).

Figure 2
Total Emissions of Four Air Toxics from Connecticut Cars and Light Trucks, Tier 2 vs. LEV II



Under Tier 2 in 2025, cars and light duty trucks would emit 418 tons of these four air toxics, but only 281 tons under LEV II. This means 137 tons less would be emitted from cars and light trucks under LEV II in 2025, a savings of more than 30 percent (see Figure 3).

Figure 3
Percentage of Additional Emissions Reductions of Four Air Toxics from Cars and Light Duty Trucks: LEV II over Tier 2, 2025



These benefits, over and above what the federal program is expected to achieve, represent a significant portion of the total air toxic emissions. The **additional savings of LEV II over Tier 2 in 2025 is equivalent to taking approximately 193,000 of today's vehicles off the road, or eliminating nearly a third of current point source emissions of the 33 air toxics of greatest concern.**[u] These savings are associated with significant health benefits, which will be discussed in more detail in the following section.

t VMT fractions for 2007 were used and no change in VMT splits was assumed to take place thereafter. Use of 2007 VMT splits is likely to underestimate the percentage of future travel by light duty trucks, since these have been growing as a percentage of the vehicle fleet. However, Connecticut-specific forecasts of VMT splits were not available for use in this analysis. A higher percentage of LDTs would lead to higher absolute emissions, but the percentage benefits would not change substantially. Since most LDTs will be included in the sales base required for calculating ZEV credits, it would have little effect on the benefits of the ZEV part of the LEV II program.

u Based on data in the National Emissions Inventory, version 3. See Appendix B for a discussion of the limitations of this inventory.

Benefits of Reducing Air Toxics in Connecticut

Once we calculated emission reductions based on the Mobile 6.2 output, we estimated the effects these reductions would have on cancer and non-cancer hazards in Connecticut.

Cancer

Methodology

We analyzed the EPA air toxics inventory data from 1996, compiled in a project called the National Air Toxics Assessment (NATA). Year 1996 is the most recent year for which sufficiently detailed information is available. NATA data includes modeled ambient air toxic concentrations across Connecticut census tracts, and indicates the highway motor vehicle contribution to ambient concentrations.

We used the Mobile 6.2 results to calculate the amount in which ambient emissions are reduced across census tracts for Tier 2 and LEV II.* Based on the reductions in the light duty vehicle contributions to ambient emissions, we calculated ambient emissions reductions for the census tracts with ambient pollutant concentrations at the 10th, mean, and 90th percentile. Table 2 lists the modeled 1996 ambient concentrations, as well as the expected ambient concentrations for LEV II and Tier 2 in 2025. Although 1996 estimates may not reflect 2003 conditions, small changes in these ambient levels do not impact health numbers significantly.

Table 2. Percentile Distribution of Ambient Concentrations of Four Air Toxics across Connecticut Census Tracts (ug/m^3) in 1996 and 2025, Tier 2 vs. LEV II

	1996[w]		2025	
	Mean	10th-90th Percentile	Mean	10th-90th Percentile
Tier 2				
Acetaldehyde	0.77	0.33-1.03	0.52	0.20-0.70
Benzene	1.28	0.84-1.71	0.94	0.56-1.25
1,3-Butadiene	0.05	0.02-0.09	0.03	0.01-0.05
Formaldehyde	1.15	0.68-1.49	0.94	0.50-1.21
LEV II				
Acetaldehyde	0.77	0.33-1.03	0.50	0.19-0.67
Benzene	1.28	0.84-1.71	0.89	0.54-1.19
1,3-Butadiene	0.05	0.02-0.09	0.02	0.01-0.04
Formaldehyde	1.15	0.68-1.49	0.92	0.49-1.19

Next, we calculated reductions in expected annual cancer cases in Connecticut, given changes in ambient concentrations. More specifically, we used Integrated Risk Information System (IRIS) unit risk estimates (the same estimates used by the Connecticut Department of Public Health[14]) to calculate the added cancer risk per million for each of the four air toxics in the year 2025, given the reduction in ambient concentrations for each scenario. We then multiplied each of the added cancer risk per million values by the Connecticut population estimates[15] to calculate the number of cancers in Connecticut that might be avoided by adopting LEV II.

w Note that toxics levels are the same in 1996; they are included under Tier 2 and LEV II for ease of comparison with 2025 concentrations.

Findings[x]

The calculated added cancer risk per million values are listed in Table 3 below.

Table 3
Added Cancer Risk per Million due to Motor Vehicles, 2025

	Tier 2	LEV II
Acetaldehyde	1.1	1.1
Benzene	7.3	6.9
1,3-butadiene	8.4	5.6
Formaldehyde	12.2	12.0
Total	**29.1**	**26.0**

In 1996, the motor vehicle contribution to cancer risk in the average census tract in Connecticut from these four chemicals was 40.6 per million residents. Table 3 shows that the risk would be reduced to 26 per million in the average census tract under LEV II and 29.1 per million for Tier 2. That is 3.1 per million residents fewer than Tier 2. **This means there would be 12 percent fewer cancers attributable to these four air toxics in 2025 for LEV II compared to Tier 2.**

In the more heavily trafficked census tracts the benefit is even greater. In 1996, the motor vehicle contribution to cancer risk in the 90th percentile census tract in Connecticut from these four chemicals was 60.2 per million residents. With the LEV II program the risk would be reduced to 37.4 per million in the 90th percentile census tract; Tier 2 risk would be reduced to 41.4 per million. That is a 4.0 per million residents greater reduction than Tier 2.

If we were to relate a 12 percent decrease in these cancers to the projected population in 2025, we might expect about 13 fewer cases per year for LEV II compared to Tier 2. Over a ten-year period, this would result in about 130 fewer cancers. Using a 70-year lifetime, there would be about 910 fewer people acquiring cancer in their lifetime due to these automotive emissions.

Non-cancer

Methodology

To estimate the non-cancer benefits of adopting LEV II, we obtained the 1996 NATA non-cancer hazard indices for eight respiratory irritants in each Connecticut census tract, grouped by pollutant source. We focused on respiratory hazards because these are the most well characterized non-cancer effects. However, these air toxics are likely to cause a variety of health problems beyond respiratory irritation and other effects on the lung. Many pollutants, like benzene and 1,3-butadiene, have the potential to cause harm to the human reproductive system and interfere with growth and development. Because toxicological data are insufficient, the full scale of potential benefits is unknown.

We first determined the number of Connecticut residents living in census tracts in which the respiratory irritant hazard index (HI) from highway mobile sources was greater than one. We then applied the reductions expected under Tier 2 and LEV II to the light duty vehicle contribution of the highway mobile source category[y] and recalculated the HI to determine the number of residents who would no longer be living in a census tract where the HI was greater than one. In this calculation, we assumed that the population in each census tract stays constant and that the HI from all of the other source categories stays constant over time. Only the HI for highway mobile sources changes due to the emissions decreases expected for each scenario.

The respiratory irritants hazard index (HI) is the sum of hazard quotients for eight air toxics that have similar respiratory effects (the index is mostly driven by acetaldehyde, formaldehyde, acrolein, and 1,3-butadiene). The HI for respiratory irritants is an approximation of the aggregate effect of these pollutants on the respiratory system. Aggregate exposures below a HI of one will likely not result in adverse noncancer health effects over a lifetime of exposure. A respiratory HI greater than one indicates a potential for irritation of the respiratory system.

x While the precise estimation of actual numbers of cases of disease from modeled data cannot be inferred, this information can be used to provide a ranking scale of risk and thus expected health risks. See Appendix B for more information.

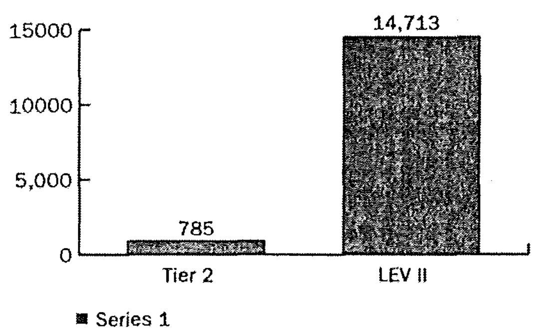
y According to national averages in 1996, approximately 80 percent of the on-road emissions for these eight air toxics were emitted from light duty vehicles.

Findings

In 1996, every Connecticut resident lived in a census tract for which the aggregate hazard index for respiratory irritants was greater than one. Highway emissions alone created a cumulative hazard index of greater than one for more than 3.2 million Connecticut residents.

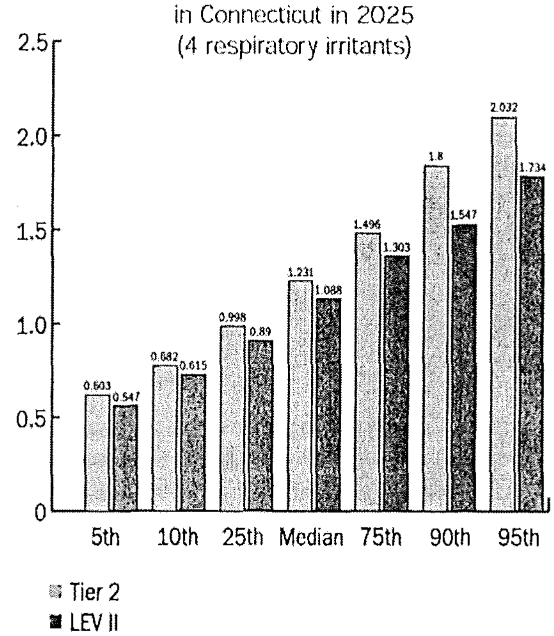
Respiratory irritant risk would drop for virtually all Connecticut residents under LEV II, giving them additional protection against respiratory illness. A reduction in light duty vehicle emissions consistent with Tier 2 in 2025 would lead to approximately 785 fewer people in the "at risk" category from respiratory irritants. A reduction in light duty vehicle emissions consistent with LEV II in 2025 would lead to approximately 14,713 fewer people in the "at risk" category from respiratory irritants. The benefit over and above what the federal program is expected to achieve is an additional 13,928 people in the lower risk category from respiratory irritants (see Figure 4).

Figure 4
Population Living in Census Tracts where Respiratory Irritants Hazard Index Shifted Below 1, 2025



In addition, a substantial reduction in an individual's hazard index can also provide meaningful relief in terms of respiratory irritation, whether the index is above or below one. Figure 5 shows that the mean hazard index from respiratory irritants is below one for a minority of census tracts under either program, and a majority of people live in census tracts where the hazard index is greater than one under either program. However, it also shows that there are significant benefits associated with LEV II: even in areas where the hazard index remains above one, residents in those census tracts will see meaningful respiratory hazard index reductions beyond what they would see under the federal program.

Figure 5
Mean hazard Index for the least to most impacted census tracts in Connecticut in 2025
(4 respiratory irritants)



Although a hazard index less than one is likely not to be associated with respiratory risk, 1.0 should not be considered an absolute "bright line." Susceptible individuals such as those with asthma can respond to very low concentrations, so it is difficult to set threshold levels for susceptible populations.[17] Hazard values are based on irritation and not the potential to induce asthma, so exacerbation of asthma can occur at doses of these pollutants below those that induce irritation.

Given that around eight percent of adults (202,000) and nine percent of Connecticut children (75,000) report having asthma,[18] and nearly five percent of the population (158,656) suffers from chronic bronchitis or emphysema,[19] a reduction in respiratory irritant risk would provide a substantial gain for many Connecticut citizens' quality of life.

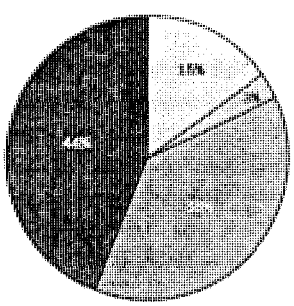
The Criteria Pollutant Problem in Connecticut

The most common air pollutants in the United States are the criteria pollutants. These six air pollutants – carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide – are known to be associated with a number of adverse health and ecological effects.

> Person-days of exceedance is a population-weighted indicator of the extent of air pollution exposure. It is a standard way to identify areas where large numbers of people are exposed to unhealthy air quality, and is calculated by multiplying the number of days when monitored concentrations of a criteria pollutant exceed a NAAQS by the total number of people living in the affected area.

The greater Connecticut region is in serious non-attainment of the health-based National Ambient Air Quality Standard (NAAQS) for ground-level ozone levels. In 1999, there were 146 days in which the eight-hour ozone standard was exceeded and 41 days in which the one-hour ozone standard was exceeded.[20] As a result, there were nearly 177 million person-days of NAAQS exceedance for the ozone eight-hour standard and more than 35 million person-days of NAAQS exceedance for the one-hour average standard. New Haven County is also in moderate non-attainment of the NAAQS for coarse particulate matter (PM10).

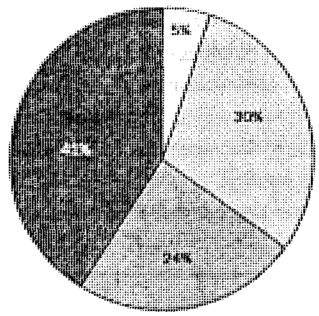
Figure 6
Connecticut Oxides of Nitrogen Emissions, 1999



Stationary Point Sources 15%
Stationary Area Sources 3%
Off-Highway Mobile Sources 38%
Highway Mobile Sources 44%

As illustrated in Figures 6 and 7[z], highway mobile sources are responsible for nearly half of nitrogen oxide (NOx) emissions and nearly a third of volatile organic compound emissions (VOCs) in Connecticut. Biogenic sources (corn, grasses, and trees) are also major sources of VOCs and NOx, but are not included in these figures.

Figure 7
Connecticut Volatile Organic Compound Emissions, 1999



Stationary Point Sources 5%
Highway Mobile Sources 30%
Off-Highway Mobile Sources 24%
Stationary Area Sources 41%

Highway mobile sources: gasoline & diesel automobiles, trucks and motorcycles

Off-highway mobile sources: non-automotive transportation; commercial, industrial, residential equipment

Stationary area sources: small commercial and industrial firms, residential paints, solvents and fuels

Stationary point sources: utilities, industrial and large commercial buildings.

The other Connecticut sources of nitrogen oxide emissions, in order of relative contribution after highway mobile sources, are off-highway mobile sources, stationary point sources, and stationary area sources. Sources of VOCs, in order of relative contribution, are stationary area sources, highway mobile sources, off-highway mobile sources, and stationary point sources.

z Data is from Connecticut Department of Environmental Protection 1999 Ozone and Carbon Monoxide State Implementation Plan (SIP) emission inventories for all non-attainment areas within the state of Connecticut. These figures are based on typical ozone summer days.

As illustrated in Table 4 below, light duty vehicles are responsible for a significant portion of Connecticut source emissions of VOCs and NOx: 29 percent of VOCs and 22 percent of NOx. The LEV II program will help Connecticut meet the NAAQS for ground level ozone – and lessen the impact of criteria pollutants on the health of state citizens.

Table 4
Connecticut Anthropogenic Source Emissions of VOCs and NOx, 1999

	Light Duty Vehicles	All Other Mobile Sources	Stationary Area Sources
Volatile Organic Compounds	29%	25%	46%
Oxides of Nitrogen	22%	60%	18%

It should also be noted, however, that there are high background levels of ozone precursors in Connecticut, due to transport of pollution across state lines and emissions from biogenic sources such as trees, corn, and grasses. While LEV II will not have an effect on these portions of the emissions inventory, it means that levels in the state, not including Connecticut motor vehicle emissions, are above threshold levels for health effects. Reducing ozone by targeting vehicle emissions standards will help address the portion of emissions the state can control. This reduction will result in substantial public health benefits, as discussed later in this section.

In our analysis, we modeled changes in VOCs and NOx for Tier 2 and LEV II over time. These two pollutants are emitted from motor vehicles and form ozone in the presence of sunlight in the atmosphere. We did not model particulate matter (PM) because of the uncertainty regarding the portion of light duty vehicles that might run on diesel fuel in the years to come (airborne PM largely comes from diesel vehicles).

Health Impacts

Epidemiological studies have linked the criteria pollutants to endpoints such as cardiovascular disease, respiratory disease, and overall mortality. The following is a summary of the health effects associated with exposure to selected pollutants:

- **Nitrogen Dioxide (NO_2)**, formed in the atmosphere when nitric oxide, a product of combustion, is oxidized. NO_2 can irritate the eyes, nose, throat, and lungs, and possibly cause shortness of breath, tire ness, and nausea. Breathing high levels of nitrogen oxides can cause bronchitis and pneumonia, and lower resistance to respiratory infections.

- **Volatile Organic Compounds (VOCs)** emitted in the Northeast come largely from automobiles and chemical manufacturing facilities, though sources also include dry cleaners and other processes that use solvent and paint. Many VOCs are carcinogenic, as well as liver and reproductive toxins. They are the most common chemicals found to produce health effects in Center for Disease Control and Prevention studies at hazardous waste sites. VOCs are precursors to ozone.

- **Ozone (O_3)** is formed when precursor compounds like VOCs and oxides of nitrogen (NOx) react in the presence of sunlight. The reactivity of ozone causes health problems because it damages lung tissue, reduces lung function and sensitizes the lungs to other irritants. Ozone causes a variety of respiratory symptoms including chest tightness, cough, and asthma exacerbation. High levels of ozone are associated with increased emergency room visits, hospitalizations, and mortality.

- **Particulate Matter (PM)** includes dust, dirt, soot, and liquid droplets directly emitted into the air by sources such as cars, factories and power plants. It is a mixture of particles that can affect breathing, aggravate existing respiratory and cardiovascular disease, alter the body's defense systems against foreign materials, and damage lung tissue, contributing to cancer and premature death.

Criteria Pollutant Reductions as a Result of LEV II

Methodology

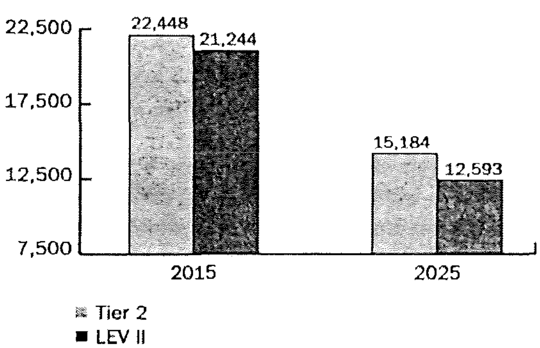
We used EPA's Mobile 6 software to model emissions changes for volatile organic compounds (VOCs) and oxides of nitrogen (NOx), precursors of ground-level ozone. The methodology for determining the reductions of criteria pollutants for both scenarios is the same as that described above for the toxic air pollutants. See "Calculation of Air Toxics, VOC, and NOx Emissions" in Appendix A for more information.

Findings

Emissions from cars and light duty trucks will be significantly lower under the LEV II program in 2015 and 2025, compared to Tier 2 (see Figure 8).

Figure 8

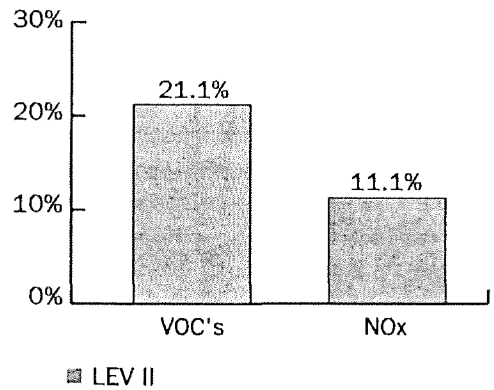
VOC and NOx Emission Reductions from Cars and Light Duty Trucks in 2015, 2025: LEV II vs. Tier 2



In fact, LEV II implementation would reduce VOCs by 1,862 tons and reduce NOx by 640 tons more than Tier 2, a 20 percent additional benefit for VOCs and 11 percent additional benefit for NOx (See Figure 9). **This reduction would be equivalent to taking nearly 264,000 vehicles off of today's roads, or eliminating more than 25 percent of current point source emissions of VOCs and about two percent of current point[aa] source emissions of NOx in Connecticut.[bb]**

Figure 9

Percentage of Additional Savings of VOC and NOx Emissions: LEV II over Tier 2, 2025



aa Point sources are large, stationary facilities such as power plants.

bb This calculation is based on data in the Connecticut Department of Environmental Protection 1999 Ozone and Carbon Monoxide State Implementation Plan (SIP) emission inventories for all non-attainment areas within the state of Connecticut.

Benefits of Reducing Criteria Pollutants in Connecticut

Health Benefits

Criteria pollutant reductions as a result of LEV II adoption are likely to be associated with a variety of health benefits for Connecticut citizens. While we do not estimate the health benefits of ozone due to reductions in ozone precursors in the state because of the difficulty in estimating the rate of ozone transformation in the Connecticut airshed, ozone precursor reductions that occur in Connecticut are likely to benefit citizens in Connecticut and in neighboring states.

Documented health risks associated with ozone include decreased lung function and increased respiratory problems, as well as irreversible lung damage from long-term exposures. There is also a substantial body of literature drawn from both clinical and epidemiological studies which demonstrates an association between many common air pollutants, such as ozone and particulate matter, and asthma-related respiratory symptoms, such as wheezing, coughing, and shortness of breath.[21] Outdoor concentrations of ozone and particulate matter, at concentrations typically encountered in ambient air, are associated with an increase in asthma symptoms, an increase in medication use, and a decrease in lung function.

The Clean Air Task Force[22] also estimated that from April to October of 1997, ozone was responsible for approximately 100,000 asthma attacks in Connecticut, as well as about 2,600 emergency room visits for all respiratory problems.

The substantial contribution of motor vehicles to ozone pollution is well established. In fact, light duty vehicles account for about a third of ozone precursor emissions in the state. While the source contributions to ambient concentrations of particulate matter are less understood, light duty vehicles are likely to play a role in at least some of the formation of fine particle pollution in most urban areas.[23]

Air quality improvements resulting from LEV II adoption will result in significant public health benefits, especially for particularly susceptible Connecticut citizens, and those who frequently experience unhealthy concentrations of ozone and fine particulate matter.

Air Quality Planning Benefits

Attainment of the NAAQS for ozone and particulate matter is likely to present a long-term challenge for Connecticut. As a result of Connecticut's non-attainment of NAAQS – a violation of the Clean Air Act – the state must file a state implementation plan (SIP) with the EPA, describing how it will meet the national standards. The SIP is a legally binding document. States that fail to comply with their SIP face sanctions, including restrictions on federal highway funding for highway construction and mandatory emissions reductions before new emissions sources can be commissioned.

In SIP planning, the state typically considers the expected tonnage of VOCs and NOx reduced per day when it develops new regulations. For example, recent action on Municipal Waste Combustors is expected to reduce NOx pollution by 1.5 tons per day, and regulations on portable fuels are expected to eliminate three tons of VOCs per day. The additional reductions expected from LEV II over the federal program are in line with past regulatory actions. In 2015, the expected benefit of LEV II over the federal program for VOCs and NOx is three tons per day, and the expected benefit in 2025 is seven tons per day. This seven-ton per day reduction from LEV II is thus equivalent to two to three regulatory actions directed at other source categories, such as point or area sources.

Diesel

This report would not be complete without a discussion of diesel, as diesel engines[cc] emit large quantities of fine particulate matter, nitrogen oxides, and toxic chemicals that harm human health and the environment. The emissions from diesel engines have been linked to a wide range of health impacts including increased lung disease, heart disease, cancer, premature death, and the exacerbation of asthma. In addition, diesel pollution adds to environmental impacts such as smog, acid rain and nutrient pollution to waterways, and crop and forest damage.

More than 4,000 tons of diesel exhaust is emitted into Connecticut air each year.[dd] Because diesel is the hazardous air pollutant with the highest contribution to cancer risk in the state and the average Connecticut resident's cancer risk from diesel emissions is approximately 700 times greater than the risk level deemed acceptable by the U.S. Environmental Protection Agency, the benefits of reducing diesel emissions are significant. Landmark standards to clean up diesel trucks and buses on the highways are now being phased in nationally, and will result in significant savings in terms of health benefits for Connecticut citizens. However, given the magnitude of harm threatened by diesel emissions and the long time frame over which the federal standards will be implemented, states can play an important role in further limiting risks posed by diesel particulates.

Connecticut has taken a leadership role in addressing diesel pollution by implementing a number of voluntary programs, such as a diesel bus retrofit program in Norwich, retrofit of construction equipment at the Quinnipiac Bridge project, and continued study of retrofits with supplementary environmental project monies. The state is also working to implement an ultra-low sulfur diesel fuel program and developing an environmental education curriculum to include a discussion of diesel in air quality modules.

Connecticut is now working to curb pollution from diesel emissions, but more can be done in the state in the future. Given the contribution light duty vehicles make to pollution levels in the state, attention to cars and light duty trucks through the LEV II program could be an important next step in making further air quality and public health gains in the state.

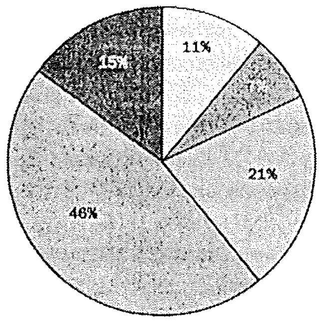
cc Diesel engines power on-road sources (buses and trucks), non-road sources (construction and agricultural equipment), and other important transportation sources, such as rail and marine vessels.

dd EPA did not inventory emissions of diesel particulate from stationary sources, which contribute a small percentage of diesel emissions (as per US PIRG, 2002).

Greenhouse Gases in Connecticut

Connecticut's transportation sector is the single largest and fastest growing portion of total greenhouse gases.

Figure 10
Tons of CO_2 Emitted in Connecticut, 1999



- Commercial 11%
- Industrial 7%
- Residential 21%
- Transportation 46%
- Utility 15%

The state transportation sector's share of CO_2 and other greenhouse gas (GHG) emissions grew to approximately 45 percent of the total in 2000[ee], up from 35 percent in 1990[24]. This trend is expected to increase in Connecticut alongside the rise in vehicle-miles traveled (VMT) in the state.

Passenger cars and light duty trucks are responsible for 61 percent of transportation GHG emissions. Thus, these vehicles are responsible for 28 percent of all greenhouse gas emissions in Connecticut, compared to 22 percent nationally[25].

Global warming carries potentially serious health and ecological impacts for the northeast in general and Connecticut in particular. As the temperature rises and air quality diminishes, respiratory disease and heat related problems increase[26]. Increasing temperature is also likely to affect disease vectors, changing the pattern of communicable diseases.

In this section, we report the benefits for Tier 2 and two LEV II scenarios, as the reductions vary depending on how the Zero-Emission Vehicle (ZEV) mandate of the LEV II program is implemented, and how readily advanced technology is accepted by consumers.

Greenhouse Gas Benefits of LEV II

Methodology

The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model Version 1.5a, developed by Argonne National Laboratory and the University of Chicago, was used to calculate CO_2 and other GHG emissions for different vehicle technologies. GREET is a full-fuel-cycle model that accounts for upstream emissions in the production and transport of fuel, as well as downstream emissions resulting from vehicle operation. GREET was used with its default inputs, with two primary exceptions: first, custom assumptions were developed for the relative efficiencies of various vehicle technologies; and second, an electricity generating mix specific to the Northeast was used. See "Calculation of Greenhouse Gas Emissions" in Appendix A for more information about these and other key assumptions used in this modeling process.

ee The State Energy Data Report inventory significantly understates carbon dioxide emissions. Better data has not yet been published, but data currently out for review suggests that in 2000, the transportation sector contributed 16.1 MMT, or 38 percent to total carbon dioxide emissions from fossil fuel combustion (42.85 MMT). Fuel combustion is the predominant human-generated source of greenhouse gas emissions.

As illustrated in Table 4, the GREET model documents that hybrid-electric vehicles emit 28 percent fewer greenhouse gas emissions than conventional gasoline vehicles. This model also illustrates that hydrogen fuel cell vehicles gain nearly two times the greenhouse gas benefits of battery-electric vehicles, emitting nearly 60 percent fewer greenhouse gases than a conventional gasoline vehicle (in our analysis, hydrogen fuel is assumed to be produced from natural gas at centralized power plants).

Table 4. Greenhouse Gas Emissions: Percent Change Relative to Conventional Gasoline Vehicles

	Hybrid-Electric	Battery-Electric	Hydrogen Fuel Cell
Total energy (Btu/mi)	-29%	-3%	-48%
CO_2 (g/mi)	-29%	-31%	-58%
GHGs (g/mi CO_2 equiv)	-28%	-32%	-59%

These differences in advanced technology emissions rates translate to differences in emissions benefits for LEV II, depending on the type of technology assumed to meet the ZEV mandate. In the following discussion, we present two variations for how the ZEV requirement could be met, and implications for greenhouse gas emissions for each. Assumptions for how automakers would meet the requirements for each of these LEV II scenarios are shown in Table 5 below.

ZEV Scenario One: Minimum Compliance

This scenario presents the baseline LEV II program, in which minimally achievable reductions from LEV II implementation are attained, with automakers meeting the minimum ZEV requirements of the program. In this case, we assume that a majority of passenger cars and the lightest class of trucks meeting the credit obligations are PZEVs.

ZEV Scenario Two: Advanced Technology with Minimum Compliance

This scenario assumes the Alternative Compliance Path (ACP), allowing manufacturers to meet the ZEV mandate with PZEVs and AT PZEVs. In this case, we assume that hybrid technology (AT PZEVs) successfully penetrates all of the vehicle classes, but minimum ZEV credit requirements are not exceeded.

Table 5. Credit Obligations (Large Manufacturers)[ff]

Model Year	Percent Obligation			
	ZEV Scenario 1. Minimum Compliance			
	ZEV	AT PZEV	PZEV	Total
2007	2.0%	2.0%	6.0%	10.0%
2012	3.0%	3.0%	6.0%	12.0%
2015	4.0%	4.0%	6.0%	14.0%
2018	5.0%	5.0%	6.0%	16.0%
2020+	5.0%	5.0%	6.0%	16.0%
	ZEV Scenario 2. Advanced Technology with Minimum Compliance			
	ZEV	AT PZEV	PZEV	Total
2007	0.0 %	8.0%	2.0%	10%
2012	0.47%	9.5%	2.0%	12%
2015	0.94%	11.1%	2.0%	14%
2018	5.0 %	9.0%	2.0%	16%
2020+	5.0 %	9.0%	2.0%	16%

ff These percentages of ZEVs and near ZEVs called for under LEV II do not represent actual percentages of cars sold. Makers have the opportunity to earn credits toward the requirement that reduces the actual number of ZEVs they produce.

ZEVs refer to pure ZEVs such as full-function electric vehicles; AT PZEVs can be assumed to be hybrid-electric vehicles; PZEVs are super ultra low-emission vehicles (SULEVs).

Findings

More aggressive adoption of advanced technology leads to greater reductions in greenhouse gas emissions. Meeting only the minimal requirements of LEV II with the ZEV mandate results in 2.2 percent less GHG emissions from cars and light duty trucks than under the federal program. If there is more aggressive adoption of alternative technology in passenger cars and light trucks (LDV and LDT1), but without exceeding minimum ZEV credit requirements, benefits are higher. The greatest benefits, 4.2 percent fewer emissions from cars and light duty trucks compared to Tier 2, occur when hybrid technology is also introduced into heavier truck classes (LDT2) (see Table 6).

Table 6
Greenhouse Gas Savings from Cars and Light Duty Trucks due to LEV II Adoption: Percent Savings vs. Tier 2

	ZEV Scenario 1. Minimum Compliance	ZEV Scenario 2. Advanced Technology with Minimum Compliance
2015	0.8%	2.4%
2025	2.2%	4.2%

The 2.2 percent savings for LEV II Minimum Compliance (ZEV Scenario 1) over Tier 2 translates to a benefit of 420,000 metric tons of carbon dioxide equivalent in 2025; the 4.2 percent savings for Scenario 2 is a benefit of 810,000 metric tons in 2025.

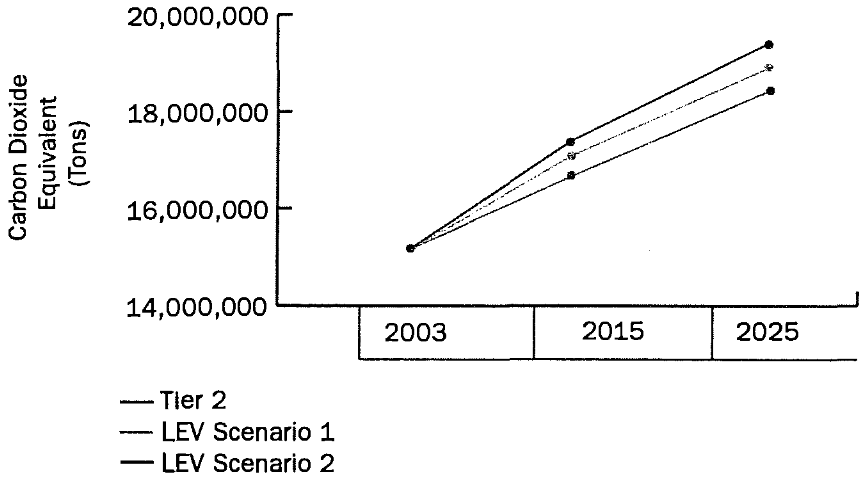
According to the State Energy Data Report (SEDR), carbon dioxide emissions were 36.96 million metric tons (MMT) in 1999; the transportation sector contributed 16.61 MMT, or 45 percent, to the total.[88] In terms of 1999 GHG emissions, the additional benefits expected from the LEV II scenarios over Tier 2 are summarized in Table 7 below. It shows that for Scenario Two, for example, emissions savings expected for LEV II over Tier 2 is equivalent to eliminating approximately five percent of current transportation emissions or two percent of the current total greenhouse gas emissions.

Table 7
Additional Greenhouse Gas Reductions for Two ZEV Scenarios for LEV II Compared to Tier 2, 2025: Percent of Current Emissions

	Percentage of Current Transportation Emissions	Percentage of Current Total GHG Emissions
Scenario 1	2.5%	1.1%
Scenario 2	4.9%	2.2%

88 Data currently out for review suggests that in 2000, the transportation sector contributed 16.1 MMT, or 38 percent to total carbon dioxide emissions from fossil fuel combustion (42.85 MMT). Fuel combustion is the predominant human-generated source of greenhouse gas emissions. Adjusting for this updated inventory will lower the percentages listed in the right-hand column of Table 7 slightly – 1.0% of current total GHG emissions for Scenario One and 1.9% for Scenario Two.

Figure 11
Carbon Dioxide Emissions from Cars
and Light Duty Trucks: Tier 2 vs. LEV II



In Figure 11, we plotted the expected carbon dioxide emissions from light duty vehicles over time for Tier 2 and both LEV II scenarios. It illustrates that there is a significant GHG benefit for LEV II. This difference is particularly important since reductions in GHG emissions can also similarly reduce associated co-pollutants that affect human health, provided these reductions are based on lowered fossil-fuel combustion.[27]

While our analysis details modest greenhouse gas emissions reductions for minimal compliance with the ZEV mandate of LEV II, GHG emission benefits increase given more aggressive adoption of advanced automobile technologies. GHG emissions reductions associated with the ZEV component of the California program are an important first step and will increase over time as California further strengthens its GHG standards.

The 2002 Pavley Bill (A.B. 1493) requires the California Air Resources Board (CARB) to adopt regulations to "achieve the maximum feasible reduction" in emissions linked to global warming for light duty vehicles beginning in model year 2009. The Pavley Program requires that regulations provide manufacturers "flexibility, to the extent possible" and be cost effective. While the actual magnitude of reductions to be achieved under Pavley is uncertain, there is widespread agreement on the potential for the program to achieve significant GHG benefits in a cost-effective manner. For example, the Massachusetts Institute of Technology completed a key study examining the feasibility of a wide range of automotive technologies to reduce GHG emissions by the year 2020 (Weiss et al. 2000).[hh] The report concludes that an evolved conventional car could reduce GHG emissions by 36 percent without radical new technologies or major cost increases. The evolved conventional car incorporates a refined, more efficient engine, improved transmission gearing and controls, and lightweight, streamlined body structure using existing steel structure and some aluminum and engineered plastics. These improvements create GHG emission reductions without affecting vehicle performance or model size. The assessment found that a GHG emission reduction of 61 percent is feasible by coupling hybrid-electric car technology with additional design advances, such as substantial use of lightweight materials, incorporating the most advanced internal combustion and friction reduction design, and taking advantage of additional transmission advances.

If Connecticut adopts LEV II with the ZEV mandate, it will represent an important first step in reducing GHG emissions from cars. Moreover, by adopting these existing California standards, Connecticut will create an opportunity to take advantage of the Pavley Program as it evolves and becomes part of future California clean cars standards. The MIT study documents the substantial extent of cost-effective GHG emission reductions that can be anticipated to be achieved by the Pavley Program as it matures.

hh Weiss, M.A., J.B. Haywood, I.M. Drake, A. Schafer, and F.F. AuYeung, *On the Road in 2020: A Life-Cycle Analysis of New Automobile Technologies*, Energy Laboratory Report No. MIT EL00-0003, Cambridge, MA, Massachusetts Institute of Technology, October 2000.

Conclusions

We recommend that Connecticut join neighboring states New York and Massachusetts in enacting California's emissions standards for new automobiles and light duty trucks. The LEV II program, with the ZEV component, significantly reduces air toxic, criteria pollutant, and greenhouse gas emissions beyond the federal program and has a clear impact on public health, particularly in highly trafficked transportation corridors.

Connecticut has long been working to limit emissions from stationary sources, and is now focusing substantial efforts on the important task of curbing diesel pollution. Given the impact of car and light duty truck emissions on air quality and public health, the state must address these emissions sources in order to make further air quality gains.

Adoption of LEV II with the Zero-Emission Vehicle mandate would provide significant benefits for citizens and put the state in line for further strengthening of emissions standards alongside California. Further, it would give Connecticut citizens the same cleaner cars sold in other Northeastern states at comparable prices, and would allow Connecticut to be a national leader in air pollution control.

The ZEV program would put tens of thousands of advanced-technology vehicles on Connecticut's roads by the end of the decade, at minimal cost to automakers. The program would also give Connecticut the opportunity to take advantage of further technology advances. These regulations are not likely to impact prices paid by automotive consumers in the state, and any cost differences appear minor compared to the price of an average vehicle or the economic benefits that will result from improved public health and fuel economy.

The health and environmental impacts of vehicle pollution, the trend toward increasing vehicle travel, the continuing difficulty in meeting national air quality standards for ozone, and the issue of climate change all contribute to the need to reduce vehicle emissions. LEV II is a cost-effective and technologically feasible way to reduce our dependence on foreign sources of oil, spur the growth of advanced technology, and, most importantly, make Connecticut a healthier place to live and raise a family.

Appendix A. Emissions Modeling Methodology and Assumptions

Program Structure and Sales Mix[ii]

Under the California LEV II program, the ZEV requirement begins in 2005, with the requirement that the new vehicle fleet include a minimum of 10 percent ZEVs or equivalent as obtained through ZEV credits. The ZEV credit requirement increases from 10 to 16 percent between model years 2009 and 2018, and remains at 16 percent thereafter. Under the base implementation path, in any given year, a maximum of six percent of the ZEV credit may be obtained through partial ZEVs (PZEVs); at least half of the remaining credit (two percent in 2008 and five percent in 2018) must be obtained through ZEVs. The rest can be obtained with AT PZEVs.

In Connecticut, the ZEV requirement is assumed to start in 2007. This assumes that legislation establishing this program passes in 2004, and allows the required two-year lead time for manufacturers.

In April 2003, the California Air Resources Board (CARB) amended the ZEV program to allow manufacturers the option of pursuing an Alternative Compliance Path (ACP). Under the ACP, all manufacturers must collectively produce at least 250 ZEVs in 2005-2008, 2,500 in 2009-2011, 25,000 in 2012-2014, and 50,000 in 2015-2017. At least half of the credits for these ZEVs must be from fuel cell vehicles (FCVs). During this period, the remaining credits that would have been required from ZEVs can be made up with credits for AT PZEVs. After 2017, the program reverts to its original requirements. Under the ACP, through model year 2011 FCVs sold in states other than California that have adopted the LEV II program count towards California's requirements. After year 2011, they do not count toward the requirements. The CARB resolution does not specify how other states will set their ZEV/FCV requirements in 2012-2017.

A list of the major vehicle classes referenced in this report, with an example of a traditional car for each class, is below.

GVW: gross vehicle weight = *maximum design loaded weight*

LVW: loaded vehicle weight = *actual vehicle weight plus 300 lbs.*

ALVW: adjusted loaded vehicle weight = *average GVW and actual vehicle weight*

Table 8. Vehicle Classification

CA Vehicle Class	US Vehicle Class	Weight	Example[29]
PC	LDV	All passenger cars	Honda Accord
LDT1	LDT1	0 to 6,000 lbs GVW 0 to 3,750 LVW	Toyota RAV-4
LDT2	LDT2	0 to 6,000 lbs GVW 3,751 to 5,750 lbs LVW	Ford Explorer
	LDT3	6,001 to 8,500 lbs GVW 0 to 5,750 lbs ALVW	Dodge Durango
	LDT4	6,001 to 8,500 lbs GVW 5,751 to 8,500 lbs ALVW	Chevy Suburban

ii Mobile 6 analyses were completed by Cambridge Systematics. Information in this Appendix is taken directly from Memorandum from Christopher Porter and Iris Ortiz, Cambridge Systematics to Dana Young, Connecticut Fund for the Environment, June 12, 2003.

Calculation of Air Toxics, VOC, and NOx Emissions[jj]

Methodology

Emissions of air toxics, VOC, and NOx were estimated using the Mobile 6.2 model. For each scenario, an implementation schedule (94+ LDG IMP and T2 EXH PHASE-IN files) was established consistent with sales mix assumptions. A corresponding set of 50,000-mile certification standards (T2 CERT file) was also established for the LEV II implementation schedules.

Particulate matter (PM) emissions were not analyzed. While Mobile 6.2 has the capability to output tailpipe PM emissions, it cannot easily be adopted to model the PM benefits of the LEV II program compared to the Tier 2 program. This may be an area for future analysis.

Mobile 6 Inputs

Mobile 6 input files for Connecticut were obtained from the Connecticut Department of Environmental Protection (DEP) in March 2003. These files had to be modified somewhat for Mobile 6.2. Mobile 6.2 does not allow toxics to be output in conjunction with the use of the reformulated gasoline (RFG) command. Instead, gasoline fuel parameters had to be entered in the Mobile input file. Factors for RFG in the northeast U.S. were used pursuant to EPA guidance.[30]

The following vehicle-miles traveled data was used for Connecticut.

Table 9
Vehicle-Miles Traveled
Connecticut Statewide VMT

	2003	2015	2025
LDV	36,072,065	41,331,642	44,648,587
LDT1	7,502,731	8,596,677	9,286,586
LDT2	24,960,962	28,600,510	30,895,732
LDT3	7,694,104	8,815,985	9,523,475
LDT4	3,540,946	4,057,295	4,382,891
Total	**79,770,807**	**91,402,110**	**98,737,272**

Effect of Extended Durability Requirements

The California ZEV program requires that all vehicles obtaining ZEV credits, including PZEVs and AT PZEVs, be certified to 150,000-mile durability standards instead of 120,000-mile standards as required for Tier 2 and other LEV II vehicles. Since PZEVs are expected to make up a significant percentage of the vehicle fleet, this requirement is likely to lead to additional reductions in VOC and toxics emissions beyond those estimated in the current analysis. The benefits of the 150,000-mile standard were not estimated in this study for two reasons. First, solid information to quantify these benefits was not readily available. CARB has developed a methodology for estimating increases in emissions over vehicle life ("deterioration rates") as embedded in its EMFAC2000 model, but the methodology is not directly transferable to how emissions are calculated in the Mobile 6 model. Second, the effects of the durability standard are likely to be related to the specific inspection and maintenance (I/M) program in place and to the effectiveness of I/M and on-board diagnostics (OBD) at identifying and repairing high-emitting vehicles.

Evaporative Emissions

Evaporative emissions standards are shown in Table 10.

Table 10
Evaporative Emissions Standards
for California Vehicle Classes
Three-Day Diurnal +
Hot Soak Emissions, g/test

Vehicle Class	Tier 1/ LEV I	Tier 2	LEV II	LEV II PZEV/ ZEV
LDV	2.00	0.95	0.50	0.35
LDT1, LDT2	2.00	0.95	0.65	0.50

In this analysis, it was assumed that LEV II vehicles *not certified to the zero-evaporative standards* have the same evaporative emissions levels as Tier 2 vehicles. This is consistent with EPA's assumption in the Mobile 6 model that Tier 2 and LEV II vehicles will have equal evaporative emissions benefits.[31]

jj Mobile 6 analyses were completed by Cambridge Systematics. Information in this Appendix is taken directly from Memorandum from Christopher Porter and Iris Ortiz, Cambridge Systematics to Dana Young, Connecticut Fund for the Environment, June 12, 2003.

Their assumption is based on discussions with automakers indicating that they would make one set of evaporative emissions controls that would meet both Tier 2 and LEV II standards and therefore be suitable for all 50 states. It should be noted that while there is therefore no assumed incremental benefit of the LEV II program in the Northeast, in fact the existence of the California LEV II program may be leading to lower evaporative emissions from vehicles nationwide.

Because Mobile 6 is not capable of modeling enhanced evaporative emissions standards beyond the Tier 2 requirements, post-processing adjustments of Mobile 6 output were made to account for the zero-evaporative LEV II standards. To do this, evaporative emissions output for Tier 2 vehicles were obtained by model year. For LEV II PZEV vehicles, evaporative emissions were then reduced in proportion to the ratio of LEV II zero-evaporative to Tier 2 certification standards. These ratios are 0.37 for LDVs and 0.53 for LDT1&2, in model years 2007 and beyond.

It is possible that the LEV II zero-evaporative standards could lead to actual reductions in emissions that are either larger or smaller than the proportionate reduction in certification standards. One case in which benefits might be smaller is if the proportion of high emitters (e.g., due to component failures) is not reduced in proportion to the change in certification standards. However, it is also likely that the technology introduced to meet the near-zero evaporative standards will be less prone to failure than that currently in use. A recent report by CARB staff suggests that the enhanced evaporative standards already introduced under the LEV I program have reduced the incidence of high emitters by about 50 percent. An additional reason why the proportional adjustment method could underestimate benefits is because the "near-zero" vehicles (including all PZEVs and AT PZEVs) must be certified to 150,000-mile durability standards instead of 120,000-mile standards. The greater durability requirement is likely to lead to lower evaporative emissions over the life of the vehicle. Also, the more stringent evaporative emissions standards may help to reduce other sources of evaporative emissions, including resting, running, and crankcase emissions, not covered in the diurnal + hot soak test. The "proportional adjustment" is the same methodology that EPA uses to estimate evaporative benefits of the Tier 2 program vs. existing standards.

Calculation of Greenhouse Gas Emissions[32]

The GREET Model Version 1.5a, developed by Argonne National Laboratory and the University of Chicago, was used to calculate CO_2 and other GHG emissions for different vehicle technologies. GREET is a full-fuel-cycle model that accounts for upstream emissions in the production and transport of fuel, as well as downstream emissions resulting from vehicle operation. GREET was used with its default inputs, with two primary exceptions: first, custom assumptions were developed for the relative efficiencies of various vehicle technologies; and second, an electricity generating mix specific to the Northeast was used. These and other key assumptions used in this modeling process are discussed in more detail below.

Vehicle Technology Assumptions

PZEV vehicles are assumed to be conventional gasoline engine vehicles with advanced emissions control technology. At least ten production vehicles – models produced by BMW, Ford, Honda, Nissan, Toyota, Volkswagon, and Volvo – have already been certified to PZEV standards.

Advanced Technology Vehicles (AT PZEVs and ZEVs) are assumed to be the following:

- AT PZEVs are assumed to be grid-independent gasoline-electric hybrids, similar to the Honda Civic hybrid sold today.
- Under ZEV scenario 1, pure ZEVs are assumed to be battery-electric vehicles through 2009, transitioning to hydrogen fuel cell vehicles (H2FC) between 2010 and 2013. Under ZEV scenario Two, pure ZEVs are assumed to be all H2FC vehicles. Hydrogen fuel is assumed to be produced from natural gas at centralized power plants.

Numerous other vehicle/fuel technologies could have been evaluated. For example, alternative-fuel vehicles including compressed natural gas (CNG), liquid propane gas (LPG), or methanol could potentially meet the AT PZEV standards. "Grid-connected" hybrid vehicles can obtain additional credits for a zero-emission range (running on batteries) of 20 to 60 miles. Fuel cell vehicles may also be powered by methanol or gasoline via an on-board reformer, although these would not necessarily meet ZEV standards. The technologies evaluated here were selected because they were viewed as some of the most likely technologies to be adopted that are capable of meeting the requirements established by the California ZEV program.

Energy Efficiency

CO_2 emissions depend on both the consumption of energy (upstream and downstream) to power the vehicle and the carbon content of the fuels used in this process. Energy efficiency can be thought of in two separate components:

1. The efficiency of energy use by the vehicle, i.e., the distance traveled per unit of energy (British thermal unit or kilowatt-hour) in the fuel that is put into the vehicle.

2. The overall efficiency of the fuel production process, including extraction, generation, and transmission.

The energy efficiency ratio (EER) of advanced technology vehicles to conventional gasoline vehicles is one of the required inputs of the GREET model. Energy efficiency is measured as the energy content of the fuel used in operating the vehicle per unit distance traveled. It can be thought of as a miles-per-gallon (MPG) equivalent. The EER does not reflect upstream energy consumption, which is estimated separately in the GREET model.

EERs for Advanced Technology Vehicles (ATVs) are somewhat uncertain given the emerging nature of the technologies. To identify appropriate EERs for this analysis, a literature review was undertaken. Experts were contacted and reports reviewed from organizations involved in advanced vehicle technology research, including the Office of Transportation Technologies at the Department of Energy, the Center for Transportation Research at Argonne National Laboratory, the California Air Resources Board, and the Institute of Transportation Studies at the University of California at Davis.

The following EERs were selected for this analysis:

- **Hybrid-electric vehicles (AT PZEVs):** 1.4:1. This is approximately the ratio of fuel economy on the EPA combined cycle for the 2003 Honda Civic hybrid compared to the automatic-transmission gasoline Civic, and for the Toyota Prius compared to the automatic-transmission Toyota Corolla.[33] Hypothetical evaluations of a compact, midsize, and SUV hybrid by Argonne National Laboratory also show an EER of about 1.4.[34] The anticipated 2003 Ford Escape hybrid, a small sport-utility vehicle, is rumored to obtain 35 MPG, which gives it an EER of 1.6 compared to the V6 Escape.

- **Battery-electric vehicles (ZEVs):** 2.65:1. This is midpoint of a range of values (2.4 to 2.9) estimated by Arthur D. Little in a report to the California Air Resources Board as being reasonable projections of battery-electric EERs for both the short term and the long term.[35] Other comparisons of actual battery-electric vehicles with similarly-sized gasoline vehicles typically show EERs in the range of 2 to 4, so 2.65 is viewed as a reasonably conservative estimate.[36]

- **Hydrogen fuel cell vehicles (ZEVs):** 2.6:1. EERs for fuel-cell vehicles are somewhat more speculative since production-ready vehicles do not yet exist and fuel cell systems are still undergoing rapid development. However, the Department of Energy (DOE) has evaluated the efficiency of hydrogen fuel-cell systems.[37] Current and projected efficiency for such a system is estimated between 55 and 60 percent of the energy content of the fuel, as compared to 20 to 25 percent for a gasoline engine (running at 25 percent power output). This suggests an EER of about 2.6.

As a baseline to compare energy use, conventional gasoline vehicle fuel economy was assumed to remain constant over the period of the analysis. Average fuel economy by vehicle class has remained roughly constant over the past decade, and in the absence of policy initiatives to raise fuel efficiency standards or a sustained, long-term increase in the price of oil, this trend is expected to continue. Average fuel consumption rates by vehicle class included in the GREET model, as derived from DOE estimates, are 22.4 MPG for LDVs and 16.8 MPG for LDT1 and LDT2 (up to 6,000 lb. GVWR). These are slightly lower than the fuel consumption rates embedded in Mobile 6.2 (23.9 and 18.7 MPG, respectively). Average fuel consumption and GHG emission rates for LDT3 and LDT4 classes, which are not included in the GREET model, was estimated by factoring the GREET model LDT1/2 mileage (16.8) by the ratio of Mobile 6.2 mileage for the LDT 3/4 and LDT 1/2 classes (14.4 vs. 18.7 MPG).

Emissions from Powerplants

The GREET model was also used to estimate CO_2 emissions from electricity-generating powerplants. A mix of fuel types specific to New England was used in place of the GREET model defaults, based on recent data from the Energy Information Administration (EIA).[38] This mix is shown in Table 15. "Other" fossil fuels, including municipal solid waste, tires, and other fuels, make up 4.5 percent of this mix; for the purposes of the GREET model, these fuels were included in the same category as residual oil. Other key assumptions include the percentage of natural gas and coal electricity generation from combined cycle (CC) plants, which are considerably more efficient than other plants. In this analysis, 45 percent of natural gas and 20 percent of coal generating capacity, the default values contained in GREET, is assumed to be from combined cycle plants. In this analysis, no distinction is made between "marginal" and "average" emissions rates.

Table 11
Mix of Fuels for Electricity Generation

Fuel Type	Percent
Residual Oil and "Other" Fossil Fuel	27.5%
Natural Gas	18.0%
Coal	16.3%
Non-Fossil	38.2%
Total	**100.0%**

The electricity generation mix for the Mid-Atlantic region, which includes New York state, was significantly different (including more coal and non-fossil fuels and less residual oil) but produces nearly identical CO_2 emissions according to the EIA. For simplicity, the New England mix was used throughout the analysis.

The future electricity generating mix may be affected by a number of forces, including prices of different fuels, regulatory conditions, market demand, and technological developments, which are difficult to forecast. In the absence of reliable forecasts, the mix is assumed to remain the same in future years for purposes of this analysis. This assumption may over-estimate GHG emissions from electric vehicles in future years, since GHG emissions from New England powerplants have been declining slightly given trends toward greater reliance on natural gas (which has a lower carbon content) and renewables as well as more efficient technology.

Results: GHG Emission Rates

The results of the GREET model for energy consumption, CO_2 emissions, and total GHG emissions for the different technologies evaluated are shown in Table 12.

Table 12. Energy Consumption and Greenhouse Gas Emissions[jj]

	Total				Percent Change Relative to Conv. Gasoline		
	Conv. gasoline	Hybrid-electric	Battery-electric	Hydrogen fuel cell	Hybrid-electric	Battery-electric	Hydrogen fuel cell
LDV							
Total energy (Btu/mi)	6,347	4,534	6,138	3,277	-29%	-3%	-48%
CO_2 (g/mi)	448	320	311	188	-29%	-31%	-58%
GHGs (g/mi CO_2 equiv.)	473	341	322	194	-28%	-32%	-59%
LDT1&2							
Total energy (Btu/mi)	8,463	6,045	8,184	4,369	-29%	-3%	-48%
CO_2 (g/mi)	598	427	415	251	-29%	-31%	-58%
GHGs (g/mi CO_2 equiv.)	629	452	429	259	-28%	-32%	-59%

jj Mobile 6 analyses were completed by Cambridge Systematics. Information in this Appendix is taken directly from Memorandum from Christopher Porter and Iris Ortiz, Cambridge Systematics to Dana Young, Connecticut Fund for the Environment, June 12, 2003.

Differences Compared to the EPA-Recommended LEV II Analysis Methodology[kk]

The U.S. EPA embeds assumptions about the Tier 2 program in its Mobile 6 model, specifically the sales mix of vehicles by bin by year. Instead of using the EPA default Tier 2 program, we constructed our own Tier 2 program sales mix consistent with the Tier 2 regulations.[40] Also, the U.S. EPA has circulated Mobile 6 input files (T2 EXH, T2 CERT, and 94+ LDG IMP) intended for use in modeling the benefits of the LEV II program in the northeast and other states. To better model different LEV II scenarios while retaining a fair comparison with the Tier 2 program, we created our own input files. We believe that the differences in relative LEV II vs. Tier 2 benefits as a result of the different methodologies should be minor or negligible. There are two key areas of difference: 1) the distribution of vehicle sales by bin; and 2) treatment of zero-evaporative vehicle emissions.

Sales by bin – Our analysis assumed that under the Tier 2 program, most LDV and LDT1 vehicles in 2007 and later would fall into bin 5, which is the bin with the NOx standard equal to the fleet-average target (0.07 g/mi at 120,000 miles). We assumed a small amount of scatter (5 percent bin 7, 85 percent bin 5, and 10 percent bin 3) which produces the same NOx fleet-average of 0.07 g/mi. A sensitivity analysis showed that larger amounts of scatter had little effect on the overall VOC results, although they might decrease total VOC emissions slightly. EPA took a more complex approach, assuming that manufacturers would tend to make lighter vehicles (LDV and LDT1/2) in lower bins, while making heavier vehicles (LDT3/4) in higher bins. We performed a sensitivity analysis to examine differences between our approach to modeling the Tier 2 program and EPA's approach. The differences were relatively minor; for a trial run of the LEV II Minimum Compliance scenario, the 2015 toxics benefits of LEV II vs. Tier 2 were 13.1 percent under our

version of the Tier 2 program and 11.6 percent under EPA's version of the Tier 2 program.

Our assumptions about sales of LEV II vehicles also differ. As previously noted, we constructed three different sales scenarios, reflecting different technology assumptions. Under each scenario, we attempted to create a sales mix that would meet the CARB NMOG target by model year. However, because of technology constraints (e.g. manufacturers using PZEV vehicles to meet most of their ZEV credit requirements) the fleet-average NMOG was actually forced below the CARB target. For example, in 2020 under the LEV II scenario the fleet average NMOG is 0.25 vs. 0.35 target. We believe that the scenarios previously analyzed for NESCAUM create a reasonable sensitivity analysis for the range of potential emissions benefits of the LEV II program. The Cambridge Systematics analysis for NESCAUM showed only small differences among four different LEV II sales mix scenarios.

Evaporative emissions – Guidance issued by EPA appears to suggest that zero-evaporative vehicles should be modeled by establishing the fraction of ZEV plus zero-evaporative vehicles in the 94+ LDG IMP file.[41] However, this would appear to assume that zero-evaporative vehicles actually produce zero evaporative emissions, whereas in reality they still produce a small amount of evaporative emissions. The proportional adjustment described above, applied in a post-processing manner to Mobile 6 output, appears to provide a reasonable estimate of the zero-evaporative emissions benefits.

kk This information is largely taken from Memorandum from Christopher Porter and Iris Ortiz, Cambridge Systematics to Dana Young, Connecticut Fund for the Environment, June 12, 2003.

Differences Compared to NESCAUM's Massachusetts, New York, and Vermont Report[42]

The methodology used is, for the most part, similar to the approach taken by Cambridge Systematics to model the benefits of LEV II in Massachusetts, New York, and Vermont for the Northeast States for Coordinated Air Use Management (NESCAUM).[43] Changes to this methodology for the Connecticut analysis include:

- Mobile 6.2 was used to obtain toxics emissions. For the NESCAUM work, Mobile 6.0 output was post-processed with toxics ratios from the literature, since Mobile 6.2 was not available at the time of the original analysis. Toxics emissions rates may therefore differ slightly for this work compared to the NESCAUM analysis.

- Connecticut was assumed to opt into the LEV II program beginning in 2007. For 1994-2003, Connecticut was assumed to take part in the National LEV (NLEV) program as implemented in the Northeast. For 2004-2006, Connecticut was assumed to phase in the Tier 2 program as required of all states that have not opted into the LEV II program. Beginning in 2007, 100 percent implementation of the California LEV II program is assumed.

- Emissions benefits are reported for all light duty vehicle classes (LDV, LDT1, LDT2, LDT3, and LDT4). For the NESCAUM analysis, only benefits for the LDV, LDT1, and LDT2 classes were reported.

- Emissions benefits are reported for NOx and VOC as well as toxics and GHG emissions.

- A different set of LEV II implementation scenarios was analyzed. The NESCAUM analysis found relatively small differences in benefits among four alternative LEV II implementation paths (referred to as Scenarios 2 through 5). Therefore, the LEV II Minimum Compliance scenario – which corresponds to "minimum technology requirement" LEV II program, beginning with a 2% ZEV/ 2% AT PZEV/ 6% PZEV mix was used to represent the "baseline" LEV II program.

- A ZEV Scenario II was analyzed only for GHG emissions calculations utilizing the GREET model. This scenario assumes that manufacturers meet the minimum ZEV requirement with PZEVs and AT PZEVs, and that hybrids (AT PZEVs) successfully penetrate into the LDT2 class, which includes the majority of minivans and sport-utility vehicles. In addition, this scenario assumes the minimum ZEV requirement is met through the "Alternative Compliance Path" adopted by CARB at its meeting on April 24, 2003.

- Calendar years 2015 and 2025 were evaluated, instead of 2010 and 2020. This was in order to better assess the longer-term impacts of the program.

Appendix B. Health Effects Background

Thirty Three Air Pollutants Included in the National Scale Air Toxics Assessment

acetaldehyde
acrolein
acrylonitrile
arsenic compounds
benzene
beryllium compounds
1,3-butadiene
cadmium compounds
carbon tetrachloride
chloroform
chromium compounds
coke oven emissions
1,3-dichloropropene
diesel particulate patter
ethylene dibromide
ethylene dichloride
ethylene oxide
formaldehyde
hexechlorobenzene
hydrazine
lead compounds
manganese compounds
mercury compounds
methylene chloride
nickel compounds
perchloroethylene
polychlorinated biphenyls (PCBs)
polycyclic organic matter (POM)
propylene dichloride
quinoline
1,1,2,2-tetrachloroethane
trichloroethylene
vinyl chloride

Air Toxics Health Effects

The following air pollutants are produced in significant quantities by light duty cars and trucks.

Acetaldehyde

http://www.epa.gov/ttn/atw/hlthef/acetalde.html
Acetaldehyde is a saturated aldehyde that is found in vehicle exhaust and is formed as a result of incomplete combustion of both gasoline and diesel fuel.[44] It is ubiquitous in the environment and may be formed in the body from the breakdown of ethanol. Acute (short-term) exposure to acetaldehyde results in effects including irritation of the eyes, skin, and respiratory tract. Symptoms of chronic (long-term) intoxication of acetaldehyde resemble those of alcoholism. Acetaldehyde is considered a probable human carcinogen (Group B2) based on inadequate human cancer studies and animal studies that have shown nasal tumors in rats and laryngeal tumors in hamsters.

Acrolein

http://www.epa.gov/ttn/atw/hlthef/acrolein.html
Acrolein can be formed from the breakdown of certain pollutants in outdoor air or from burning gasoline. It is extremely toxic to humans from inhalation and dermal exposure. Acute (short-term) inhalation exposure may result in upper respiratory tract irritation and congestion. No information is available on its reproductive, developmental, or carcinogenic effects in humans. The animal cancer data are limited, with one study reporting an increased incidence of adrenocortical tumors in rats exposed to acrolein in the drinking water. EPA considers acrolein a possible human carcinogen (Group C).

Benzene

http://www.epa.gov/ttn/atw/hlthef/benzene.html
Benzene is found in the air from emissions from burning coal and oil, gasoline service stations, and motor vehicle exhaust. Acute (short-term) inhalation exposure of humans to benzene may cause drowsiness, dizziness, headaches, as well as eye, skin, and respiratory tract irritation, and, at high levels, unconsciousness. Chronic (long-term) inhalation exposure has caused various disorders in the blood, including reduced numbers of red blood cells and aplastic anemia, in occupational settings. Reproductive effects have been reported for women exposed by inhalation to high levels, and adverse effects on the developing fetus have been observed in animal tests. Increased incidence of leukemia (cancer of the tissues that form white blood cells) have been observed in humans occupationally exposed to benzene. EPA has classified benzene as a human carcinogen (Group A).

1,3-Butadiene

http://www.epa.gov/ttn/atw/hlthef/butadien.html
Motor vehicle exhaust is a constant source of 1,3-butadiene. Although 1,3-butadiene breaks down quickly in the atmosphere, it is usually found in ambient air at low levels in urban and suburban areas. Acute (short-term) exposure to 1,3-butadiene by inhalation in humans results in irritation of the eyes, nasal passages, throat, and lungs. Epidemiological studies have reported a possible association between 1,3-butadiene exposure and cardiovascular diseases. Epidemiological studies of workers in rubber plants have shown an association between 1,3-butadiene exposure and increased incidence of leukemia. Animal studies have reported tumors at various sites from 1,3-butadiene exposure. EPA has classified 1,3-butadiene as a probable human carcinogen (Group B2).

Ethylbenzene

http://www.epa.gov/ttn/atw/hlthef/ethylben.html
Ethylbenzene is mainly used in the manufacture of styrene. Acute (short-term) exposure to ethylbenzene in humans results in respiratory effects, such as throat irritation and chest constriction, irritation of the eyes, and neurological effects such as dizziness. Chronic (long-term) exposure to ethylbenzene by inhalation in humans has shown conflicting results regarding its effects on the blood. Animal studies have reported effects on the blood, liver, and kidneys from chronic inhalation exposure to ethylbenzene. Limited information is available on the carcinogenic effects of ethylbenzene in humans. In a study by the National Toxicology Program (NTP), exposure to ethylbenzene by inhalation resulted in an increased incidence of kidney and testicular tumors in rats, and lung and liver tumors in mice. EPA has classified ethylbenzene as not classifiable as to human carcinogenicity (Group D).

Formaldehyde

http://www.epa.gov/ttn/atw/hlthef/formalde.html
Formaldehyde is the most prevalent aldehyde in vehicle exhaust. It is formed from incomplete combustion of both gasoline and diesel fuel and accounts for one to four percent of total exhaust TOG emissions, depending on control technology and fuel composition. It is not found in evaporative emissions.[45] Acute (short-term) and chronic (long-term) inhalation exposure to formaldehyde in humans can result in respiratory symptoms, and eye, nose, and throat irritation. Limited human studies have reported an association between formaldehyde exposure and lung and nasopharyngeal cancer. Animal inhalation studies have reported an increased incidence of nasal squamous cell cancer. EPA considers formaldehyde a probable human carcinogen (Group B1).

n-Hexane

http://www.epa.gov/ttn/atw/hlthef/hexane.html
Hexane is used to extract edible oils from seeds and vegetables, as a special-use solvent, and as a cleaning agent. Acute (short-term) inhalation exposure of humans to high levels of hexane causes mild central nervous system (CNS) effects, including dizziness, giddiness, slight nausea, and headache. Chronic (long-term) exposure to hexane in air is associated with polyneuropathy in humans, with numbness in the extremities, muscular weakness, blurred vision, headache, and fatigue observed. Neurotoxic effects have also been exhibited in rats. No information is available on the carcinogenic effects of hexane in humans or animals. EPA has classified hexane as not classifiable as to human carcinogenicity (Group D).

Methyl tert-butyl ether (MTBE)

http://www.epa.gov/ttn/atw/hlthef/methylte.html
Methyl tert-butyl ether is used as a gasoline additive. Exposure may occur by breathing air contaminated with auto exhaust or gasoline fumes while refueling autos. Respiratory irritation, dizziness, and disorientation have been reported by some motorists and occupationally exposed workers. Acute (short-term) exposure of humans to methyl tert-butyl ether also has occurred during its use asa medical treatment to dissolve cholesterol gallstones. Chronic (long-term) inhalation exposure to methyl tert-butyl ether has resulted in central nervous system (CNS) effects, respiratory irritation, liver and kidney effects, and decreased body weight gain in animals. Developmental effects have been reported in rats and mice exposed via inhalation. EPA has not classified methyl tert-butyl ether with respect to potential carcinogenicity (Group D).

Polycyclic Organic Matter

http://www.epa.gov/ttn/atw/hlthef/polycycl.html
The term polycyclic organic matter (POM) defines a broad class of compounds that includes the polycyclic aromatic hydrocarbon compounds (PAHs), of which benzo[a]pyrene is a member. POM compounds are formed primarily from combustion and are present in the atmosphere in particulate form. Sources of air emissions are diverse and include cigarette smoke, vehicle exhaust, home heating, laying tar, and grilling meat. Cancer is the major concern from exposure to POM. Epidemiologic studies have reported an increase in lung cancer in humans exposed to coke oven emissions, roofing tar emissions, and cigarette smoke; all of these mixtures contain POM compounds. Animal studies have reported respiratory tract tumors from inhalation exposure to benzo[a]pyrene and forestomach tumors, leukemia, and lung tumors from oral exposure to benzo[a]pyrene. EPA has classified seven PAHs (benzo[a]pyrene, benz[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benz[a,h]anthracene, and indeno[1,2,3-cd]pyrene) as probable human carcinogens (Group B2).

Styrene

http://www.epa.gov/ttn/atw/hlthef/styrene.html
Styrene is primarily used in the production of polystyrene plastics and resins. Acute (short-term) exposure to styrene in humans results in mucous membrane and eye irritation, and gastrointestinal effects. Chronic (long-term) exposure to styrene in humans results in effects on the central nervous system (CNS), such as headache, fatigue, weakness, and depression, CSN dysfunction, hearing loss, and peripheral neuropathy. Human studies are inconclusive on the reproductive and developmental effects of styrene; several studies did not report an increase in developmental effects in women who worked in the plastics industry, while an increased frequency of spontaneous abortions and decreased frequency of births were reported in another study. Several epidemiologic studies suggest there may be an association between styrene exposure and an increased risk of leukemia and lymphoma. However, the evidence is inconclusive due to confounding factors. EPA's Office of Research and Development has updated previous assessments on the carcinogenic potential of styrene and concluded that styrene is appropriately classified as a "possible human carcinogen" (Group C).

Toluene

http://www.epa.gov/ttn/atw/hlthef/toluene.html
Toluene is added to gasoline and used to produce benzene. Exposure to toluene may occur from breathing ambient or indoor air. The central nervous system (CNS) is the primary target organ for toluene toxicity in both humans and animals for acute (short-term) and chronic (long-term) exposures. CNS dysfunction and narcosis have been frequently observed in humans exposed to toluene by inhalation; symptoms include fatigue, sleepiness, headaches, and acute nausea. CNS depression has been reported to occur in chronic abusers exposed to high levels of toluene. Chronic inhalation exposure of humans to toluene also causes irritation of the upper respiratory tract and eyes, sore throat, dizziness, and headache. Human studies have reported developmental effects, such as CNS dysfunction, attention deficits, and minor craniofacial and limb anomalies, in the children of pregnant women exposed to toluene or mixed solvents by inhalation. Reproductive effects, including an association between exposure to toluene and an increased incidence of spontaneous abortions, have also been noted. However, these studies are not conclusive due to many confounding variables. EPA has classified toluene as not classifiable as to human carcinogenicity (Group D).

Xylenes

http://www.epa.gov/ttn/atw/hlthef/xylenes.html
Commercial or mixed xylene usually contains about 40-65% m-xylene and up to 20% each of o-xylene and p-xylene and ethylbenzene. Xylenes are released into the atmosphere as fugitive emissions from industrial sources, from auto exhaust, and through volatilization from their use as solvents. Acute (short-term) inhalation exposure to mixed xylenes in humans results in irritation of the eyes, nose, and throat, gastrointestinal effects, eye irritation, and neurological effects. Chronic (long-term) inhalation exposure of humans to mixed xylenes results primarily in central nervous system (CNS) effects, such as headache, dizziness, fatigue, tremors, and incoordination; respiratory, cardiovascular, and kidney effects have also been reported. EPA has classified mixed xylenes as not classifiable as to human carcinogenicity (Group D).

Limitations in the Emissions Inventories and Health Benefit Analyses[ll]

- Emissions inventories may underestimate the actual measured concentrations downwind from stationary sources. Further, the number of reporting industries, the covered industry groups, and reporting requirements may not be consistent from year to year.

- EPA has found that its modeled ambient air concentrations typically are lower than actual measurements of ambient concentrations of the pollutants in 1996. This indicates that estimated health risks based on the modeled data underestimate actual risks. For a detailed discussion of limitations and uncertainties involved in EPA's 1996 NATA study, see www.epa.gov/ttn/atw/nata.

- There are substantial uncertainties in modeling air toxic emissions, ambient concentrations, exposures, and risks. Cancer risk estimates should not be interpreted as an accurate prediction of any individual's health outcomes. Rather, the risk estimates provide a way to screen for these pollutants that are of public health significance.

- The one-in-one-million benchmark values used in the report serve as yardsticks to assess potential cancer risks posed by air toxics. The benchmarks are not "no risk" levels but concentrations below which there is believed to be little risk to the population. These values are designed to serve as general indicators of air quality and the sources responsible for the pollutants.

- While the pollutants studied in this report are expected to dominate the inhalation risks from outdoor sources of air toxics, other toxic air pollutants also can contribute to risks, especially in localized areas around individual sources.

- This analysis considers only outdoor, inhalation exposures. Other pathways, such as ingestion and dermal exposures, are especially important for pollutants that persist in the environment and bioaccumulate.

- This analysis considers only outdoor air exposures. Because toxics are present indoors as well, modeling only outdoor exposures underestimates potential health risks from certain pollutants.

- The study estimates annual average population exposures and lacks the refinement to assess exposures found in local hotspots.[mm] This could underestimate potential health risks if people live in hotspots where pollutant concentrations are higher than annual averages.

- The cancer risk estimates assume that people spend their lifetime (70 years) exposed to the annual average exposure concentrations estimated for their area, which could overestimate potential health risks if pollution levels decline over time or underestimate risks if people live in hotspots where pollutant concentrations are higher than area averages.

ll Caveats are directly drawn from USPIRG, 2002. Dangers of Diesel: How diesel soot and other air toxics increase Americans' risk of cancer.
mm A hotspot is a location near a highway intersection or local source.

Footnotes

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3) Battery electric vehicle
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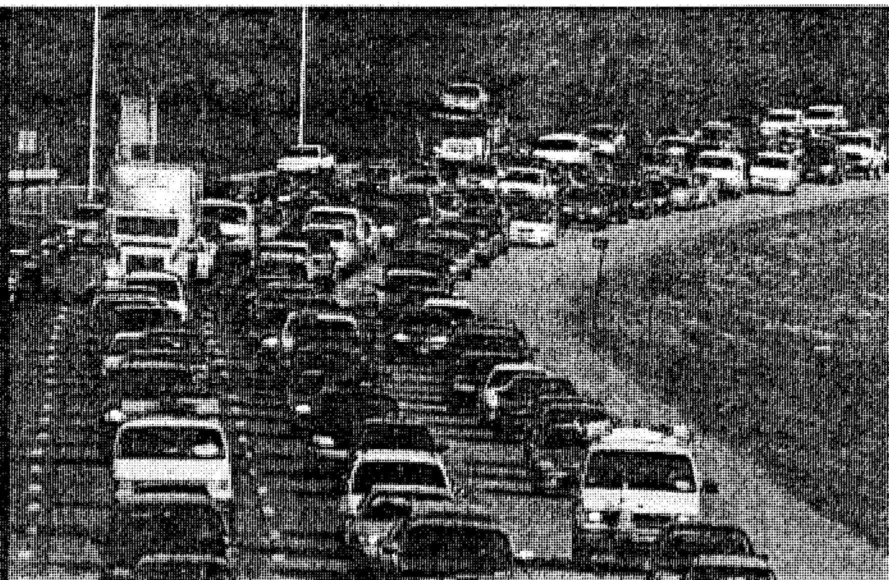

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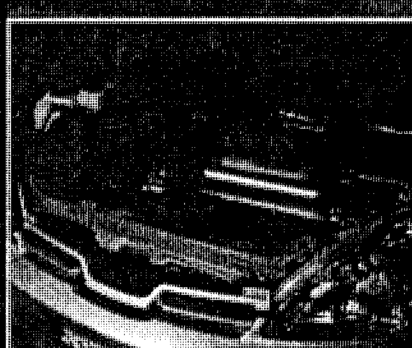

HOW STRICT LOW-EMISSION AND ZERO-EMISSION VEHICLE STANDARDS CAN CUT AIRBORNE TOXIC POLLUTION IN NEW HAMPSHIRE

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TONY DUTZIK

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Cover photos: Traffic congestion on Interstate 93 in Salem, N.H. courtesy the *Eagle-Tribune*. Hybrid-electric and battery-electric vehicles from U.S. Department of Energy, National Renewable Energy Laboratory.

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CLEAN CARS, CLEANER AIR

How Strict Low-Emission and Zero-Emission Vehicle Standards Can Cut Airborne Toxic Pollution in New Hampshire

EXECUTIVE SUMMARY

Toxic air pollutants – including those from light-duty cars and trucks – pose a significant public health threat in New Hampshire. New Hampshire could enjoy significant reductions in emissions of those pollutants, as well as emissions of smog-forming chemicals, were it to adopt Low-Emission Vehicle II (LEV II) emission standards in place in California and several other New England states.

Mobile sources – defined as cars, trucks and other non-stationary machinery – are major contributors to the toxic air pollution problem. The U.S. Environmental Protection Agency estimates that mobile sources emit 41 percent of all air toxics by weight and that on-road vehicles are responsible for approximately half that amount. Mobile sources are responsible for the vast majority of emissions of certain air toxics, such as benzene.

Analysis of 1996 data from the EPA's National-Scale Air Toxics Assessment, the most recent available, shows that residents of all 10 New Hampshire counties suffer from levels of toxic air pollution that pose excessive cancer risks to the population and may jeopardize the respiratory, reproductive and developmental health of residents as well.

Specifically:

- Ambient concentrations of 1,3-butadiene, formaldehyde and benzene exceed EPA standards for cancer risk in all 10 New Hampshire counties. Concentrations of acetaldehyde exceed the benchmark in two counties – Hillsborough and Rockingham – that contain more than half the state's population. All four chemicals are known or probable human carcinogens.
- Ambient concentrations of 1,3-butadiene in Hillsborough County were nearly 20 times higher than the EPA's cancer risk benchmark, and concentrations of formaldehyde and benzene exceeded the benchmark by factors of 14 and 10, respectively.
- Hillsborough County ranked first in ambient concentrations from on-road mobile sources for all four air toxics. Rockingham County ranked second and Strafford County ranked third.

While the past several decades have seen increasingly stringent limits on air pollution from automobiles, the effect of those tighter standards has been muted by dramatic increases in vehicle miles traveled. In New Hampshire, the annual number of vehicle miles traveled has nearly tripled since 1970.

In 1999, the EPA and the state of California adopted separate standards to further limit emissions from cars and light-duty trucks. Those standards were intended to address a variety of air pollution problems, including the emission of toxic chemicals into the air.

The California standards, known as LEV II, are much stronger than those of the EPA, known as Tier 2. LEV II includes tight limits on tailpipe and evaporative emissions of several air pollutants, including air toxics. It also includes a provision that ensures that a certain percentage of cars sold in future years will be zero-emission or near-zero-emission vehicles.

The LEV II program holds the potential for substantial environmental and public health benefits for New Hampshire – over and above the benefits gained through Tier 2. Specifically:

- LEV II would result in significant reductions in emissions of air toxics.
  - Should New Hampshire adopt the LEV II program beginning in model year 2006, light-duty vehicles would annually release about 23 percent less toxic pollution by 2020 than vehicles certified to Tier 2 standards.
  - Those emission reductions are the equivalent of taking approximately 86,000 of today's cars off the state's roads.
- LEV II would result in lower emissions of other important pollutants.

- Emissions of smog-forming nitrogen oxides and volatile organic compounds (VOCs) would both decline in the long run under LEV II. By 2020, VOC emissions from light-duty vehicles would be approximately 19 percent less under LEV II than under Tier 2.
  - Unlike Tier 2, LEV II does not "make room" for the expanded use of diesel in the light-duty vehicle fleet. Diesel is responsible for a significant portion of the toxic particulate matter in the nation's air.
- The zero-emission vehicle (ZEV) requirement is an integral feature of the LEV II program.
  - The ZEV requirement in LEV II makes the pollution reduction goals of the program more attainable. More than half of the projected reductions in air toxics emissions attained from LEV II can be attributed to vehicles covered by the ZEV requirement.
  - The ZEV requirement would also fuel the development of even cleaner technologies such as electric, fuel cell and hybrid-electric vehicles. ZEV technologies are the only ones that offer the potential of a permanent solution to the state's mobile source air toxics and smog problems and are the only ones that couple those benefits with significant reductions in global warming emissions.

The LEV II and ZEV programs will come at some additional cost to automakers and consumers. However, those costs are minor when compared to those of other air pollution reduction programs and average vehicle costs. The ZEV program has the additional benefit of reducing automobile emissions of greenhouse gases – an important step in New Hampshire's efforts to meet its commitments under the regional Climate Change Action Plan signed by Gov. Jeanne Shaheen last year. Moreover, the LEV II and ZEV rules will result in a net economic gain for the state over the long term by reducing public health costs and enhancing the state's energy security.

We recommend that the state of New Hampshire adopt the LEV II program and ZEV requirement at the earliest opportunity. Further, we recommend that the state take additional actions to encourage the deployment of ZEVs and other ultra-clean vehicles and to reduce air toxic health threats from other sources in the state.

1. INTRODUCTION

Despite its image as a place of abundant forests, breathtaking mountains and pristine lakes, New Hampshire faces significant environmental problems, among them, air pollution.

Levels of smog in New Hampshire's air exceeded EPA health standards on ten occasions during the summer of 2001, up from just once during the summer of 2000.[1] Among the biggest contributors to the problem are cars and light trucks. While tailpipe emissions from these vehicles have been reduced over the last three decades, those gains have been compromised by the dramatic increase in the number of miles traveled on the state's highways. Between 1970 and 1999, the annual number of miles traveled on New Hampshire's roads nearly tripled – from 12 million miles to 32.5 million miles.[2] With rapid residential growth continuing to occur in the state's southern tier, this trend can be expected to continue.

But smog isn't the only vehicle-related air pollution problem. Airborne toxic pollutants – such as benzene, particulate matter and formaldehyde – also pose a significant public health threat, putting hundreds of thousands of New Hampshire residents at increased risk of contracting cancer and respiratory ailments, and possibly leading to reproductive and developmental health effects as well.

Residents of every New Hampshire county – from Coos to Rockingham – breathe levels of airborne toxic contaminants that pose an excessive cancer risk under the guidelines set by federal law. Mobile sources, and especially highway vehicles like cars and trucks, are a major source of that pollution.

Over the past three decades, the federal government has adopted increasingly stringent standards to regulate emissions from motor vehicles. In 1999, it did so again, adopting "Tier 2" standards that will dramatically reduce emissions of a range of air pollutants.

But while the new standards will likely go far to address the region's smog problem, they may not be sufficient to protect New Hampshire residents from exposure to air toxics.

Thankfully, there is an alternative. The state of California – long a leader in automobile emissions reductions – has adopted a different set of emission standards that take an aggressive posture toward air toxics while also helping to combat the state's smog problem. Those standards, called the Low-Emission Vehicle II (LEV II) rule, also include a cutting-edge requirement that automakers sell significant numbers of zero-emission or near-zero emission vehicles in the near future. Recognizing the benefits of the California approach, four states – New York, Massachusetts, Maine and Vermont – have adopted some or all of the LEV II standards for themselves – leaving New Hampshire the only northern New England state without the tougher standards.

Adopting the LEV II standards in New Hampshire would lead to a significant reduction in air toxics emissions in the state over the next two decades while helping to encourage the development of technologies that could someday eliminate toxic emissions from automobiles altogether.

This approach will not be without short-term costs. But the long-term benefits – in improved public health, reduced environmental pollution and enhanced economic and energy security – are well worth the investment.

2. AIR TOXICS IN NEW HAMPSHIRE

The Environmental Protection Agency lists 188 chemicals as hazardous air pollutants (HAPs). Of those, EPA has identified 21 as coming primarily from "mobile sources" – cars, trucks and other non-stationary machinery. At least 10 of those are produced in significant quantities by light-duty cars and trucks:

- **Benzene**, which can cause leukemia and a variety of other cancers, as well as central nervous system depression at high levels of exposure. On-road vehicles produced an estimated 32 percent of all benzene emitted into New Hampshire's air in 1996.[3]
- **1,3-Butadiene**, a probable human carcinogen, which is suspected of causing respiratory problems. On-road vehicles are responsible for 35 percent of emissions in New Hampshire.
- **n-Hexane**, which is associated with neurotoxicity and whose links to cancer are unknown.
- **Formaldehyde**, a probable human carcinogen with respiratory effects. On-road vehicles are responsible for 29 percent of emissions in New Hampshire.
- **Acetaldehyde**, a probable human carcinogen that has caused reproductive health effects in animal studies. On-road vehicles are responsible for 28 percent of emissions in New Hampshire.
- **Acrolein**, a possible human carcinogen that can cause eye, nose and throat irritation.
- **Toluene**, a central nervous system depressant suspected of causing developmental problems in children whose mothers were exposed while pregnant. Its cancer links are unknown.
- **Ethylbenzene**, which has caused adverse fetal development effects in animal studies. Its cancer links are unknown.
- **Xylene**, a central nervous system depressant that has caused developmental and reproductive problems in animal studies.
- **Styrene**, a central nervous system depressant that is a possible human carcinogen.[4]

In addition, airborne **particulate matter** – the motor vehicle component of which comes largely from diesel-fueled vehicles – has also been recognized as a cause of lung cancer and respiratory problems, and is classified by California as a toxic air contaminant.

Mobile sources – which include cars, trucks and other highway and non-road motorized machinery – are major emitters of air toxics. EPA estimates that mobile sources emit 41 percent of all air toxics by weight and that on-road vehicles are responsible for approximately half that amount.[5] Several air toxics – such as benzene and toluene – are also hydrocarbons, which play an important role in the chemical reaction that creates smog.

Emissions only tell part of the air toxics story. On-road mobile source air toxics tend to achieve higher concentrations in the most populated areas of the state, where the density of vehicle emissions tends to be highest. In Hillsborough County, for instance, on-road mobile sources are responsible for 42 percent of ambient formaldehyde concentrations, 43 percent of benzene concentrations, 70 percent of 1,3-butadiene concentrations, and 69 percent of formaldehyde concentrations.[6]

In 1990, the U.S. Congress mandated that the EPA take steps to address emissions of airborne toxic chemicals. In the Clean Air Act amendments of that year, Congress set as a goal reducing the cancer risk from airborne toxins to one case of cancer for every one million residents. But twelve years later, New Hampshire residents still face cancer risks from these and other air toxics that are well above the Clean Air Act goal.

Specifically:

- Ambient concentrations of 1,3-butadiene, formaldehyde and benzene exceed EPA standards for cancer risk in all 10 New Hampshire counties. Concentrations of acetaldehyde exceed the benchmark in two counties – Hillsborough and Rockingham – that contain more than half the state's population. All four chemicals are known or probable human carcinogens. (See Table 1.)
- Ambient concentrations of 1,3-butadiene in Hillsborough County were nearly 20 times higher than the EPA's cancer risk benchmark, and concentrations of formaldehyde and benzene exceeded the benchmark by factors of 14 and 10, respectively.
- In terms of concentrations from on-road mobile sources, Hillsborough County ranked first in ambient concentrations of all four air toxics. Rockingham County ranked second and Strafford County ranked third. (See Appendix C for additional information.)

Air toxics are clearly a significant public health problem for New Hampshire. But while that threat has gained increasing recognition in recent years, it has not been adequately addressed at the federal level.

The 1970 Clean Air Act directed EPA to set health-based ambient air quality standards for six "criteria" pollutants – carbon monoxide, ground level ozone, lead, nitrogen oxide, particulate matter and sulfur dioxide. With the Clean Air Act amendments of 1990, Congress established the one-in-a-million cancer risk goal for toxic air contaminants and directed EPA to address emissions of three specific mobile source air toxics: benzene, formaldehyde and 1,3-butadiene.[7]

Despite a 54-month timeframe for developing regulations for those chemicals, it took the agency until 2001 to issue a mobile source air toxics rule – and even that rule did not take additional action to limit air toxic emissions from mobile sources. A group of environmentalists and states filed suit against the EPA in May 2001 to get the agency to fulfill the congressional mandate.[8]

Northeast States for Coordinated Air Use Management – a group representing the six New England states, New York and New Jersey – contends that the implementation of all current and proposed federal regulations, including the Tier 2 standards discussed in this report, will not achieve the

Table 1: County Rankings for Ambient Concentrations of Selected Air Toxics (µg/m³)

	1,3 Butadiene		Formaldehyde		Benzene		Acetaldehyde		
County	Ambient Concentration	State Rank	Ambient Concentration	State Rank	Ambient Concentration	State Rank	Ambient Concentration	State Rank	Average Rank
Hillsborough	***0.071***	***1***	***1.089***	***1***	***1.343***	***1***	***0.581***	***1***	1.0
Rockingham	***0.043***	***3***	***0.893***	***2***	***1.163***	***3***	***0.481***	***2***	2.5
Belknap	***0.064***	***2***	***0.625***	***5***	***1.265***	***2***	0.200	5	3.5
Strafford	***0.031***	***6***	***0.638***	***4***	***0.896***	***6***	0.263	3	4.8
Merrimack	***0.029***	***9***	***0.652***	***3***	***0.912***	***4***	0.250	4	5.0
Carroll	***0.032***	***4***	***0.458***	***10***	***0.911***	***5***	0.095	9	7.0
Cheshire	***0.029***	***8***	***0.573***	***6***	***0.735***	***9***	0.166	6	7.3
Grafton	***0.031***	***7***	***0.492***	***9***	***0.835***	***7***	0.104	8	7.8
Sullivan	***0.026***	***10***	***0.526***	***7***	***0.769***	***8***	0.135	7	8.0
Coos	***0.032***	***5***	***0.520***	***8***	***0.651***	***10***	0.068	10	8.3

****Bolded and italacized exceed cancer risk benchmarks.***

cancer risk reductions called for by the Clean Air Act.[9]

Achieving that goal – and protecting the health of New Hampshire residents – will require additional action. The LEV II standards are the best option available to New Hampshire to meet this threat.

3. AUTO EMISSIONS STANDARDS

A common theme runs through the history of automobile emissions standards in the United States. Whenever the time has come to take action to protect the environment and public health from vehicle emissions, California has led the rest of the nation.

That should be no surprise. With its automobile-centered culture and smog-conducive climate, California has typically felt the negative effects of vehicle emissions earlier and with greater severity than elsewhere in the country.

In 1961, California required installation of the first automobile emissions control device in the country. In 1966, it was the first state to adopt tailpipe emissions standards for specific pollutants. Three years later, the state issued the first set of pollutant-specific air quality standards. In the latter two cases, the federal government followed suit within two years with similar regulations.

In 1970, the federal government took a major step forward with the passage of the original Clean Air Act, which called for the first national tailpipe emissions standards and set the overall framework that has governed automobile emission regulation since.[10] The 1970s and 1980s saw the progressive tightening of existing air quality standards, the installation of new pollution control equipment, and the elimination of leaded gasoline – all of which led to significant reductions in automobile emissions.

But even as federal air pollution rules grew more stringent, federal law preserved a special place for California. From the very early days of air pollution regulation, California has been empowered to issue its own vehicle emissions standards because of the state's urgent air pollution problems.

With the Clean Air Act of 1990, the federal government further tightened emissions standards at the federal level. The law also required the EPA to reassess the need for even tighter standards for the 2004 model year and beyond.

The 1990 act also preserved the right of states to adopt more protective emission standards based on those adopted in California. By the mid-1990s, New York and Massachusetts had adopted the California rules, with Vermont and Maine following suit later. States were barred from issuing standards that differed from the federal or California rules – a provision intended to prevent automakers from being forced to market 50 different cars in 50 states.

While Congress was acting to tighten air pollution standards at the national level, California was not sitting still. In 1990, the state adopted its low-emission vehicle (LEV) and zero-emission vehicle (ZEV) standards. The LEV standards, which were far tighter than the prevailing federal standards at the time, allowed manufacturers to certify vehicles to a series of emissions "bins," provided that their fleets met an overall average standard for non-methane organic gas (NMOG) – a class of pollutants that includes many air toxics and smog precursors – that declined over time. The law also required automakers to manufacture a certain percentage of ZEVs, beginning with 2 percent in 1998 and increasing to 10 percent by 2003.[11]

In 1994, following up on the 1990 Clean Air Act Amendments, the U.S. EPA issued its Tier 1 rule, which phased in tighter emissions standards for cars and some light trucks. Several years later, in an effort to stave off the implementation of the ZEV requirement by other states, the auto industry and federal government agreed to a new National Low Emission Vehicle (NLEV) program that went into effect in the northeastern states in 1999 and nationwide in 2001. The NLEV standards include further reductions in tailpipe emissions, mirroring the reductions included in California's original LEV standards.

In 1999, both California and the federal government adopted tough new standards designed to limit air pollution emissions from a wide range of motor vehicles beginning in the 2004 model year. The California program was called LEV II; the federal program, Tier 2.

There are many similarities between the two programs. In fact, they have more in common than not.

Both adopted the "bin" system pioneered in California's 1990 LEV I standards. The system gives manufacturers the flexibility to produce a mix of higher- and lower-polluting vehicles as long as their entire fleet meets overall emission reduction targets. Both programs also eliminated the "SUV loophole" that exempted many light trucks from the tough emissions standards in place for passenger cars (although a similar loophole still exists in federal fuel efficiency standards). And both established tighter emission levels for vehicles regardless of the type of fuel they use.[12]

But there are several key differences between the two programs. Among these are:

- The two programs measure compliance against different benchmark pollutants.
- There is significant difference in the reductions required for "evaporative emissions" – those emissions that come from sources other than vehicle exhaust.
- The federal standards do not require the production and sale of technology-stimulating zero-emission vehicles.

How Standards Are Enforced

For both the California LEV II and the federal Tier 2 programs, the amount of emissions permitted for a vehicle depends on its vehicle class and weight. With the 1999 changes, the Tier 2 and LEV II programs have adopted a generally similar set of classifications for passenger cars (known as PCs or LDVs) and light trucks (LDTs). (See Table 2.)

To determine if vehicles are in compliance with clean air standards, vehicles are tested according to standardized test procedures, with their engines aged to simulate conditions at their "full useful life," which is currently defined as 120,000 miles under both California and federal standards. In certain cases, regulations also stipulate "intermediate life" standards, which are measured at 50,000 miles.

For the sake of clarity, this report will refer to vehicles by their federal classifications. Occasionally, we will refer to "heavy" and "light" light-duty trucks. Heavy light-duty trucks (or HLDTs) comprise the LDT3 and LDT4 categories in the federal classifications, while light light-duty trucks (LLDTs) represent the LDT1 and LDT2 categories. Further, whenever standards are mentioned, they should be assumed to be for the full (120,000 mile) useful life, unless otherwise stated.

Table 2: Federal and California Light-Duty Vehicle Classes[13]

CA Vehicle Class	Weight	US Vehicle Class	Weight
PC	All passenger cars	LDV	All passenger cars
LDT1	0-3,750 lbs. LVW	LDT1	0-6,000 lbs. GVW 0-3,750 lbs. LVW
LDT2	3,751 lbs. LVW- 8,500 lbs. GVW	LDT2	0-6,000 lbs. GVW 3,751-5,750 lbs. LVW
		LDT3	6,001-8,500 lbs. GVW 0-5,750 lbs. ALVW
		LDT4	6,001-8,500 lbs. GVW 5,751-8,500 lbs. ALVW

LVW: Loaded Vehicle Weight=actual vehicle weight plus 300 lbs.

GVW: Gross Vehicle Weight=maximum design loaded weight

ALVW: Adjusted Loaded Vehicle Weight=average of GVW and actual vehicle weight

While many think of pollution as primarily coming from a vehicle's tailpipe, there are other sources as well. Approximately half of all hydrocarbon emissions from vehicles come from evaporative emissions – those emissions that emanate from engines, fuel systems and other parts of the vehicle both while it is running and while it is sitting still.[14]

Those emissions include:

- **Running losses** (about 47 percent of evaporative emissions) – Running losses include leakage from the fuel and exhaust systems as the car is being driven.
- **Hot soak emissions** (about 38 percent) – Hot soak emissions include releases from the carburetor or fuel injector that occur when a car is cooling off following a trip.
- **Diurnal emissions** (about 10 percent) – Emissions that take place due to "breathing" of the gas tank caused by changes in ambient temperature (i.e. the car being heated and cooled by the sun).
- **Resting losses** (about 4 percent) – Leakage from a car while it is resting.[15]

Both the California and federal programs include new limits on evaporative emissions, although the federal standards are much weaker than the California standards. Compliance with evaporative emission standards is determined by putting a vehicle through a set testing procedure that simulates changing ambient temperatures and the effects of engine cooling following a drive.

NMOG, NMHC and VOCs

Historically, federal and California regulations have used a variety of measures to gauge the release of toxic and smog-forming pollutants from motor vehicles. The Tier 2 and LEV II rules both measure tailpipe emissions of non-methane organic gases (NMOG), a class of pollutants that includes hydrocarbons (except methane) and various other reactive organic substances such as alcohols, ketones, aldehydes and ethers. Some previous standards have been communicated in terms of non-methane hydrocarbons (NMHC), which do not include non-hydrocarbon reactive gases. Still other standards are communicated in terms of volatile organic compounds (VOCs), which include all the components of NMOG but exempt some non-reactive hydrocarbons. All three measures include a variety of air toxics, but not necessarily the same ones.

The three measures yield roughly equivalent amounts of motor vehicle emissions and are often used interchangeably. In this report, overall tailpipe and evaporative emissions reductions are presented in terms of NMHC. These values were then converted to NMOG to analyze emissions of specific air toxics and VOCs. For a more detailed discussion of this topic, see Appendix A.

Tailpipe Emission Standards

Federal Tier 2 Rule

The foundation of the Tier 2 rule is a fleet average emission standard for nitrogen oxides (NOx) – a key precursor of smog – of 0.07 grams/mile, a significant reduction from earlier federal standards. The NOx standard is to be phased in for cars and LLDTs beginning in 2004, with the standards to be fully phased in for the 2007 model year. HLDTs and medium-duty passenger vehicles (MDPVs, a class of larger passenger vehicles that includes conversion vans) will be subject to interim standards, which will be phased in beginning in 2004, and the full Tier 2 standards, which will be phased in beginning in 2008. All vehicles will comply with the new standards beginning in 2009.[16]

The new rules also give manufacturers an incentive to certify their vehicles to Tier 2 standards ahead of schedule, by allowing them to bank credits toward future compliance with the rules.

Manufacturers will have the flexibility to certify their vehicles to one of a number of "bins," provided that their fleets meet the

Table 3: Tier 2 Tailpipe Emission Standards (grams/mile)[17]

Bin No.	NOx	NMOG	CO	Formaldehyde	PM	Notes
11	0.9	0.280	7.3	0.032	0.12	a,c
10	0.6	0.156/0.230	4.2/6.4	0.018/0.027	0.08	a,b,d
9	0.3	0.09/0.18	4.2	0.018	0.06	a,b,e
8	0.2	0.125/0.156	4.2	0.018	0.02	b,f
7	0.15	0.09	4.2	0.018	0.02	
6	0.1	0.09	4.2	0.018	0.01	
5	0.07	0.09	4.2	0.018	0.01	
4	0.04	0.07	2.1	0.011	0.01	
3	0.03	0.055	2.1	0.011	0.01	
2	0.02	0.01	2.1	0.004	0.01	
1	0	0	0	0	0	

Notes:

a) This bin is deleted at the end of the 2006 model year (end of 2008 model year for LDT3-4 and MDPVs).
b) Higher NMOG, CO and formaldehyde values apply for LDT3-4 and MDPVs only.
c) This bin is only for MDPVs.
d) Optional NMOG standard of 0.280 g/mi applies for qualifying LDT4s and qualifying MDPVs only.
e) Optional NMOG standard of 0.130 g/mi applies for qualifying LDT2s only.
f) Higher NMOG standard deleted at end of 2008 model year.

0.07 g/mi average NOx requirement. In practice, the bins will allow manufacturers to produce some vehicles that emit more than 0.07 g/mi of NOx, as long as they also manufacture vehicles certified to bins with tighter NOx requirements.

The bins are structured to ensure that emissions of other air pollutants – including NMOG (which includes many air toxics), carbon monoxide (CO), formaldehyde, and particulate matter for diesel vehicles (PM) – are reduced along with NOx.

The Tier 2 standards guarantee that, at full phase-in, light-duty cars and trucks will emit no more than 0.09 g/mi of NMOG – the highest level allowed in any permanent bin. In fact, emissions will likely be less, as automakers certify some vehicles to bins 1 through 4 in an effort to balance out higher NOx-emitting vehicles in their fleets.

California LEV II Rule

In contrast to the federal rules based on NOx, the California LEV II standards are based on fleet average emissions of non-methane organic gases (NMOG) – which include some smog precursors as well as many air toxics.

The LEV II standards require all cars and light-duty trucks to meet a steadily declining fleet average NMOG requirement beginning in 2004. In the first year, cars and light light-duty trucks (LLDTs) must meet a fleet average of 0.053 g/mi NMOG when tested at 50,000 miles intermediate life, while heavy light-duty trucks (HLDTs) must meet a fleet average of 0.085 g/mi. Those averages gradually decline to 0.035 g/mi. for cars and LLDTs and 0.043 for HLDTs by 2010. (See Table 4.)

As is the case in Tier 2, manufacturers can certify their cars to any one of a number of

Table 4: LEV II Fleet Average NMOG Standards for Light-Duty Vehicle Classes (grams/mile)[18]

Model Year	All PCs; LDTs 0-3,750 lbs. LVW	LDTs 3,751 lbs. LVW-8,500 lbs. GVW
2004	0.053	0.085
2005	0.049	0.076
2006	0.046	0.062
2007	0.043	0.055
2008	0.040	0.050
2009	0.038	0.047
2010+	0.035	0.043

Bin	NMOG	CO	NOx	Formaldehyde	PM
LEV[20]	0.075/0.09	3.4/4.2	0.05/0.07	0.015/0.018	NA/0.01
ULEV	0.04/0.055	1.7/2.1	0.05/0.07	0.008/0.011	NA/0.01
SULEV	NA/0.01	NA/1.0	NA/0.02	NA/0.004	NA/0.01
ZEV	0	0	0	0	0

Table 5: LEV II Light-Duty Emission Bins at Intermediate and Full Useful Life (grams/mile)[19]

LEV=low-emission vehicle, ULEV=ultra low-emission vehicle, SULEV=super low-emission vehicle

emissions "bins"– as long as their fleet average emissions of NMOG meet the standards. The declining NMOG fleet averages will result in manufacturers certifying a greater proportion of their cars to cleaner bins as the years go by.

In the early years of LEV II, manufacturers can still certify a portion of their vehicles to the earlier LEV I standards, but the fleet averages in LEV II still apply. After 2006, the following emissions bins apply. (See Table 5)

It must also be noted both federal and California standards impose new limits on emissions from medium-duty passenger vehicles (e.g. large passenger vans). Because medium-duty vehicles make up only a small portion of the U.S. vehicle fleet, this analysis focuses primarily on light-duty vehicles, which make up 90 percent of all vehicle miles traveled in the U.S.[21]

Evaporative Emission Standards

In addition to limiting tailpipe emissions, both the Tier 2 and LEV II standards include new rules to limit evaporative emissions. Both rules keep in place limits on running loss emissions that are the same for California and the rest of the nation. The main difference is in limits on diurnal and hot-soak emissions. Those emissions are measured by two sets of tests. The three-day diurnal-plus-hot-soak test measures the evaporative emissions produced during a set of vehicle operations. The two-day test is a supplemental testing procedure designed to ensure adequate purging of the emission control canister during vehicle operation.[22] (See Table 6.)

How They Stack Up

Although both the LEV II and Tier 2 programs will result in substantial reductions in emissions, a direct comparison between the programs shows that LEV II is much stronger:

- **The LEV II program will lead to greater tailpipe emissions reductions upon full phase-in.** As noted above, the federal Tier 2 program will result in maximum fleet-average NMOG emissions of 0.09 grams/mile. Vehicles certified to Tier 2 standards will likely have somewhat lower emissions of NMOG than the 0.09 g/mi upper limit, as manufacturers certify their vehicles to cleaner bins in order to meet the fleet-average NOx requirement. The declining fleet average NMOG standard in LEV II, however, ensures that California cars will eventually release significantly less NMOG – and, therefore,

Table 6: Evaporative Emission Standards for Three-Day Diurnal Plus Hot Soak Test (in grams/test)

Class	California	Federal
Passenger cars	0.5	0.95
Light-duty trucks <6,000 lbs. GVW	0.65	0.95
Light-duty trucks 6,000-8,500 lbs. GVW	0.9	1.2

fewer air toxics – than cars certified under Tier 2. An analysis of the potential reduction in air toxics in New Hampshire that would result from adoption of LEV II follows in the next chapter.

A similar situation is likely to occur for the two chemical precursors of smog: volatile organic compounds and nitrogen oxides. Because VOC emissions are closely tied to emissions of NMOG, New Hampshire will experience a significant decline in VOC releases as the LEV II program progresses. (See next chapter for a more detailed analysis.)

Reductions in NOx emissions are expected to be similar for the early years of both the Tier 2 and LEV II programs. However, as California's fleet-average standard for NMOG tightens, more super-low-emission and zero-emission vehicles will be required to meet the standards, driving down NOx emissions significantly.

Detailed analysis conducted by the Massachusetts Department of Environmental Protection and the New York State Department of Environmental Conservation confirms the long-term NOx reduction benefits of LEV II. The Massachusetts DEP estimated that adoption of LEV II would result in a 19 percent reduction in NOx emissions compared to Tier 2 levels by 2020.[23] New York's DEC estimated that LEV II would attain a fleet average for NOx that is nearly 29 percent lower than the final fleet average attained by Tier 2 upon full implementation of both programs.[24]

- **Tier 2 could allow for continued use of dirtier vehicles.** Even at full phase-in, the Tier 2 program preserves the use of two bins – Bin 6 and Bin 7 – that permit greater emissions of certain pollutants than the LEV II standards.

  Use of the higher NOx emission levels in Bins 6 and 7 would require manufacturers to also certify some vehicles to cleaner bins in order to meet the federal fleet average requirement for NOx.

  The more significant difference, however, is in Bin 7's standard for particulate matter, which is double that of the highest LEV II bin. Some analysts suggest that such an approach would open the door for greater sales of diesel vehicles, which are a major source of particulate pollution.[25]

- **LEV II will generate greater reductions in evaporative emissions than Tier 2.** The California standards represent a nearly 80 percent reduction in evaporative emissions from previous standards, while the federal Tier 2 standards represent only a 50 percent reduction.[26]

4. Emissions Reductions in New Hampshire

Air Toxics Reductions Under LEV II

Adoption of the LEV II standards would result in a 23 percent reduction in light-duty emissions of air toxics by 2020 compared with Tier 2 emission standards, according to an analysis of models and data compiled by EPA, the Massachusetts Department of Environmental Protection and other agencies.

Tailpipe NMHC Emission Benefits

By 2020, state adoption of LEV II would result in a reduction of about 1 million pounds – or 28 percent – of annual tailpipe non-methane hydrocarbon (NMHC) emissions in New Hampshire when compared to Tier 2 standards. (See Table 7.) NMHC emissions are closely related to emissions of NMOG, which includes the bulk of EPA-regulated mobile source air toxics present in light-duty exhaust.

Most of the difference between the two standards comes from passenger cars and light light-duty trucks. These vehicles were already subject to stringent emissions limits before Tier 2 and LEV II, meaning that older LDVs and LLDTs still on the road in 2020 will make up a smaller percentage of the pollution from vehicles in those weight classes than will older HLDTs. Moreover, the high percentage reduction under LEV II reflects the program's phase-in of more stringent limits on NMOG releases from LDVs and LDT1s over time – an aggressive posture not found in Tier 2.

Evaporative NMHC Emission Benefits

The LEV II program would also bring about significant reductions in evaporative NMHC emissions – the source of about half of all NMHC released into the air from motor vehicles.

By 2020, light-duty vehicles in New Hampshire would release about 401,000 fewer pounds of NMHC – or about 11 percent – under LEV II evaporative emission standards as opposed to those in Tier 2. (See Table 8.)

Total NMHC Reductions

Combining the tailpipe and evaporative emission benefits of LEV II leads to the conclusion that total light-duty NMHC emissions would be about 1.4 million pounds per year less in New Hampshire by 2020 – or 20 percent – under LEV II as opposed to Tier 2. (See Table 9.)

Reductions in Air Toxics

The EPA regulates 21 mobile source air toxics (see Appendix D), of which a smaller number, approximately 10, are present in detectable levels in light-duty vehicle exhaust and evaporative emissions. With the exception of diesel particulate matter, which is addressed in the next section, the NMOG category of emissions includes the bulk of EPA-regulated mobile source air toxics from light-duty vehicles.

These specific chemicals are not measured individually. But chemical speciation pro-

Table 7: Estimated New Hampshire Tailpipe NMHC Emissions in 2020 Under Tier 2 and LEV II (in thousand pounds)

Vehicle Class	Tier 2	LEV II	Difference	Pct. Difference
LDV	996	606	390	39%
LDT 1/2	1,662	1,180	481	29%
LDT 3/4	1,071	914	157	15%
TOTAL	**3,729**	**2,700**	**1,029**	**28%**

Table 8: Light-Duty Evaporative NMHC Emissions in 2020 Under Tier 2/LEV II (in thousand pounds)

Vehicle Class	Tier 2	LEV II	Difference	Pct. Difference
LDV	1,222	1,047	175	14%
LDT 1/2	1,708	1,537	171	10%
LDT 3/4	668	612	56	8%
TOTAL	**3,598**	**3,197**	**401**	**11%**

Table 9: Total NMHC Emissions from Light-Duty Vehicles in 2020 under Tier 2/LEV II (in thousand pounds)

	NMHC Emissions
LEV II	5,897
Tier 2	7,327
Total Reduction	**1,430**
Pct. Reduction	**20%**

files, which detail the chemical composition of NMOG, allow us to determine the potential reductions in emissions of particular air toxics.

Applying EPA-generated speciation profiles to the LEV II-generated NMHC emission reductions detailed above yields a projected annual reduction under LEV II of 354,000 pounds – or approximately 23 percent – of the 10 air toxics listed in Table 10.[27]

Estimating that the average car on the road today in New Hampshire produces approximately 4.1 pounds of air toxics per year, the additional emissions reductions under LEV II compared with Tier 2 will be equivalent to taking approximately 86,000 of today's cars off the road by 2020.[28]

Table 10: Air Toxics Emissions by Light-Duty Fleet Under Tier 2/LEV II, 2020 (in thousand pounds)

	Tier 2	LEV II	Difference
1,3- BUTADIENE	22	16	6
N-HEXANE	118	100	18
FORMALDEHYDE	49	35	13
ACETALDEHYDE	22	16	6
ACROLEIN	2.7	1.9	0.7
BENZENE	255	196	58
TOLUENE	615	471	145
ETHYLBENZENE	94	73	21
XYLENE	343	262	81
STYRENE	15	11	4
TOTAL AIR TOXICS	**1,536**	**1,182**	**354**
PCT. REDUCTION			**23%**

Reductions in Volatile Organic Compounds

As noted above, the declining NMOG certification standards in LEV II will eventually force automakers to certify increasing numbers of cars to cleaner emission "bins" – a move that will lead to long-term reductions in emissions of NOx, an important ozone precursor.

However, those declining standards will also lead to reductions in the other main precursor of smog: volatile organic compounds, or VOCs.

In addition to containing a variety of toxic substances, the NMOG category of emissions also includes many volatile compounds that react with NOx in the atmosphere and sunlight to form smog. By reducing NMOG emissions through LEV II, New Hampshire can enjoy commensurate reductions in VOCs. By 2020, adoption of the LEV II standards would result in a reduction of 1.4 million pounds of VOC emissions – or 19 percent – when compared to Tier 2. (See Table 11.)

The Impact of Diesel

No discussion of mobile-source air toxics would be complete without referencing one of the most dangerous pollutants: diesel particulate matter (PM).

Currently, light-duty vehicles are responsible for only a small portion of the particulate matter emitted into the nation's air. The EPA estimates that even without the Tier 2 standards, emissions from light-duty vehicles would make up only 1.4 percent of all emissions of PM by 2007.

However, there is little certainty as to what portion of light-duty vehicles will run on diesel fuel in the years to come. In making its Tier 2 rule, the EPA posited a scenario in which as many as 9 percent of all passenger cars and 24 percent of light trucks sold in 2020 are running on diesel.[29]

As noted above, the Tier 2 rule allows some greater flexibility for manufacturers to produce diesel-fueled vehicles because of more lenient particulate matter standards. In one bin, PM standards are double the maximum level allowed in any bin under LEV II. Manufacturers might be tempted to take advantage of that leniency due to the greater fuel efficiency of diesel engines.

The EPA projects that tighter limits on sulfur in gasoline (enacted at the same time as Tier 2) will offset the increased production of light-duty diesel vehicles, such that its Tier 2 standards will result in total light-duty PM emissions remaining roughly the same in 2020 as today.[30]

In contrast, California's LEV II emissions standards would not make room for the widespread introduction of light-duty diesel vehicles to the marketplace. Combined with standards that reduce the sulfur content of gasoline, California's standards will lead to steep reductions in light-duty PM emissions.

Cost

Adopting the LEV II standards will not be without costs to automakers or consumers. However, those costs appear minor when compared to the price of an average vehicle or to the economic benefits that will result from improved public health.

The best gauge of the added cost of LEV II versus Tier 2 comes from a cost analysis by the California Air Resources Board (CARB). This analysis projected the additional cost of upgrading a 2003 model year vehicle certified to the ULEV bin in the original LEV I standards to a ULEV or SULEV under LEV II. The LEV I ULEV bin includes NMOG emission levels that are roughly comparable to the final Tier 2 standards, but NOx levels that are between four and twelve times higher than Tier 2. Thus, CARB's estimate – while the best available – likely overstates the additional cost of upgrading Tier 2 vehicles to meet the LEV II standards.[31]

Table 11: VOC Emissions Under LEV II vs. Tier 2, 2020 (thousand pounds)

	Tier 2	LEV II	Difference	Pct. Difference
Tailpipe	3,718	2,692	1,026	28%
Evaporative	3,705	3,292	413	11%
Total VOC	**7,423**	**5,984**	**1,439**	**19%**

CARB estimated that the incremental per-vehicle cost of LEV II would range from as little as $71 to upgrade an LDT1 to meet the LEV II ULEV standard to $304 to upgrade a heavy light-duty truck to meet the LEV II SULEV standard.[32] These figures include CARB's $25 per vehicle estimated cost of complying with LEV II's evaporative emission standards. (See Table 12.)

The LEV II standards also appear to be cost-effective when compared to other means of reducing pollution from mobile sources. CARB estimated that the additional cost would translate to approximately $1.00 for every pound of pollution reduced, compared to $5.00 per pound for other mobile source reduction programs and $10.00 per pound for many stationary source programs.[33]

The increase in cost under LEV II also appears small when compared to the average cost of a new motor vehicle, currently about $24,800.[34] The cost of adopting the program, then, translates to less than one percent of vehicle price in almost all cases.

Unfortunately, CARB did not go on to estimate the societal benefits – in reduced public health costs, averted sick days, and the like – that would result from adoption of LEV II. However, EPA did conduct such an analysis for its adoption of Tier 2 standards. EPA estimated that its Tier 2 standards will lead

Table 12: Incremental Per Vehicle Cost of LEV II ULEVs and SULEVs Versus LEV I ULEVs

	LEV II ULEV	LEV II SULEV
LDV	$96	$156
LDT1	$71	$130
LDT2-4	$209	$304

to the annual avoidance of 4,300 premature deaths nationwide, 2,300 cases of bronchitis, and numerous lost work days, hospital visits and other costs.[35] The net economic benefit of the policy to society at full implementation in 2030, EPA estimated, would be between $8.5 billion and $20 billion.[36]

Because the marginal cost of eliminating pollution increases as pollution controls tighten, it would be improper to extrapolate the potential societal benefit of the LEV II program from the EPA analysis. Since LEV II will reduce air toxics concentrations in New Hampshire – and the risks of cancer and other health problems that they pose – it is reasonable to assume that the program would result in a significant additional net economic benefit to the state.

5. THE ZERO EMISSION VEHICLE REQUIREMENT

The zero-emission vehicle (ZEV) requirement in the LEV II standards makes possible much of the emission reductions gained through the program, while promoting the development and use of advanced technology cars that could lead to further emission reductions in the future.

The ZEV requirement – as it has developed in California and been adopted by other states – is a complicated program. It has also had a tortuous history, thanks in large part to the consistent and vehement opposition of the automobile and oil industries, which have employed litigation, lobbying and public relations strategies to undo the program and prevent its spread.

Yet California's experience with the ZEV program to date has already spurred innovation in a wide range of zero-emission and low-emission vehicle technologies, from traditional electric cars to new options such as fuel-cell and hybrid-electric vehicles.

The History of ZEV

The original zero-emission vehicle program was unveiled as part of California's Low-Emission Vehicle program in 1990. As originally constructed, the plan was to have required that two percent of cars sold in California would be ZEVs by 1998, five percent by 2001, and ten percent by 2003.

In 1996, the California Air Resources Board amended the ZEV regulations in keeping with a memorandum of agreement it negotiated with seven major auto manufacturers. The agreement called for the lifting of all ZEV requirements prior to 2003 in exchange for automakers' pledge to produce for sale between 1,250 and 3,750 advanced battery electric vehicles between 1998 and 2000.[37]

In 1998, the board again amended the ZEV program, creating partial ZEV (PZEV) credits for vehicles that achieve near-zero emissions (commensurate with the SULEV emission standard) and have zero evaporative emissions. The credits served to reduce the number of "pure ZEVs" that would have to be sold by manufacturers in 2003, while increasing the overall number of cleaner vehicles on the road.

As California was adjusting its ZEV rules, a set of eastern states were positioning themselves to adopt the LEV standards and the ZEV rules that come with them. By 1996, four eastern states – New York, Massachusetts, Maine and Vermont – had adopted some or all of the LEV/ZEV program.

In the early 1990s, it looked for a time as though the LEV and ZEV programs would take hold throughout the northeast. Acting as the Ozone Transport Commission (OTC – a body created under the 1990 Clean Air Act), the northeastern states petitioned EPA to mandate adoption of the LEV program from Maine to Virginia.

The OTC's petition was later thrown out in one of many legal actions filed by automakers against the LEV program in the northeast. However, the EPA and automakers negotiated to develop a voluntary program that could supplant LEV/ZEV in the northeastern states that hadn't already adopted it.

In 1998, that voluntary program – the National Low-Emission Vehicle (NLEV) program – took effect, requiring automakers to sell cars meeting roughly the same standards as the original LEV program in New Hampshire and other northeastern states by 1999 and across the country by 2001. However, the program did not include the ZEV requirement. And it came with a promise from the northeastern states that hadn't already adopted LEV that they would not adopt California standards that would take effect before the 2006 model year.

In 2001, CARB again altered the ZEV program, reducing the percentage of pure ZEVs required in the initial years of the program to two percent and allowing manufacturers to claim additional ZEV credits. Those changes are now making their way through the regulatory process.

In the northeastern states that had adopted the ZEV program, meanwhile, state officials have proposed an alternative compliance strategy that would delay the introduction of pure ZEVs, while encouraging the early introduction of vehicles meeting PZEV criteria.[38] The plan is currently in the process of being finalized as this report goes to press.

In its short history, then, the ZEV program has been through several incarnations, weathered many political and legal battles, and remains in flux even now.

For the purpose of this report, we will assume that the version of the ZEV program that would be considered for adoption by New Hampshire is the version that was adopted by CARB in 2001, for which detailed regulations are currently being written.

How It Works

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

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

The complexity of California's credit scheme makes it impossible to predict how many of each type of ZEV or PZEV vehicle will be on the road by 2020. Moreover, rapid changes in technology could render even CARB's initial assumptions invalid.

The key elements of the program are as follows:

- **Pure ZEVs** – The California rules require that two percent of the cars sold by large volume manufacturers by 2003 be "pure ZEVs"; those with no tailpipe or fuel-related evaporative emissions. Currently, that means electric cars, but it is expected that this will soon lead to commercial introduction of hydrogen fuel cells. In early years of the program, manufacturers can meet the requirement either with "full function" ZEVs, or with "city" or "neighborhood" electric vehicles that have a smaller range and travel at lower speeds. Credits for neighborhood electric vehicles are scheduled to decrease over time, so that by 2006 they will count for only 0.15 of a full-function ZEV.[39]
- **Advanced technology PZEVs (AT-PZEVs)** – Manufacturers will be allowed to satisfy up to two percent of the 10 percent ZEV requirement by marketing AT-PZEVs powered by compressed natural gas, hybrid-electric motors, methanol fuel cells, or other very clean means. Such vehicles must meet the strict SULEV emissions standards, have "zero" evaporative emissions, and have their emissions control systems under warranty for 150,000 miles.[40] Current hybrid-electric vehicles such as the Toyota Prius do not yet meet those standards. If manufacturers fail to fulfill the two percent allocated to AT-PZEVs, they must sell pure ZEVs instead.
- **Partial ZEV (PZEV) credits** – The California law also allows manufacturers to meet up to 6 percent of the 10 percent ZEV requirement by marketing cars that meet 150,000 mile SULEV emissions standards, the state's zero evaporative emissions standards, and other criteria. These cars, which can be powered by internal combustion engines, are eligible for partial credit toward the ZEV mandate. Under the 2001 rules, their introduction will be phased in between 2003 and 2006.
- **Other credits** – Automakers can also receive additional credits for early introduction of ZEVs or for including technologies that enhance vehicle performance, such as fast recharging, extended range, and extended warranties on batteries or fuel cells.
- **Scope** – In the initial years of the program, the ZEV requirement applies only to passenger cars and light trucks in the LDT1

category. Beginning in 2007, heavier sport utility vehicles, pickup trucks and vans will be phased into the sales figures used to calculate the ZEV requirement.

Another important change adopted by CARB in 2001 is a gradual ratcheting up of the ZEV requirement from 10 percent to 16 percent over the next two decades as shown in Table 13.

However, the ample opportunities for additional credits and multipliers available to manufacturers will significantly reduce the amount of vehicles that must be sold – particularly in the early years of the program.

Assuming that New Hampshire implements the ZEV requirement beginning in 2006 – and that implementation takes place in a similar fashion as it is expected to in California – approximately 8,000 pure ZEVs would be on the road in New Hampshire in 2020, along with approximately 44,000 AT-PZEVs and 316,000 PZEVs, based on a CARB projection of how automakers will satisfy the ZEV requirement over the next 20 years.[42] (See Table 14.)

Were New Hampshire to adopt the alternative compliance plan under consideration in other northeastern states, the number of pure ZEVs and AT-PZEVs required in the first two years of the program would be reduced, while the number of PZEVs would remain roughly the same. Because the number of pure ZEVs and AT-PZEVs required in the early years of the program is already low, the alternative plan would not have a significant impact on the number of clean cars on the road in New Hampshire by 2020.

Even with the small number of pure ZEVs required by the new version of the California standards, the overall ZEV program has the potential to bring two major benefits to New Hampshire. It makes possible the impressive reductions in air toxics and other pollutants called for by LEV II and it fosters the development of new technologies that can make automobiles much cleaner in the years to come.

Table 13: ZEV Percentage Requirement[41]

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

Emissions Benefits

As noted above, the ZEV requirement is separate from the overall fleet-average emissions goals set out by the LEV II standards. In other words, automakers must meet the LEV II emission targets, regardless of how many, or what type, of ZEVs they put on the road. On the other hand, it can be argued that meeting LEV II's increasingly stringent emissions requirements will only be possible with the significant number of ultra-clean cars required under the ZEV program. Between the 2004 and 2010 model years, California's fleet-average standard for non-methane organic gases is scheduled to be reduced by 34 percent for cars and LDT1s and 50 percent for LDT2-4s. Coincidentally, these are the same years when the ZEV requirement is in the process of phase-in.

Using CARB's predictions of how automakers will comply with the ZEV rule, and applying them to New Hampshire, the tailpipe NMOG emissions of ZEV, PZEV and AT-PZEV vehicles on the road in the state in 2020 would be approximately 112,000 pounds, provided that all ZEV and PZEV vehicles adhere to applicable emis-

Table 14: Estimated ZEVs and PZEVs in Use in Hampshire: 2020

	Cars	Percentage of light-duty fleet
ZEVs	8,000	0.7%
AT-PZEVs	43,700	3.9%
PZEVs	315,600	27.9%

Table 15: NMHC Emissions of Vehicles Used to Comply with ZEV Requirement vs. Comparable Tier 2 Vehicles, 2020 (in thousand pounds)[44]

	NMHC (thousand lbs.)
ZEV, PZEV, AT-PZEV emissions	112
Tier 2 vehicle emissions	919
Difference	**807**
Total emissions savings LEV II vs. Tier 2	**1,430**
Pct. of savings due to vehicles covered by ZEV requirement	**56%**

sion standards for their entire lives. The same number of vehicles meeting the anticipated fleet average for NMOG under Tier 2 would emit 919,000 pounds.[43]

As stated in the previous section, the LEV II standards would result in a reduction of 1.4 million pounds of NMHC in 2020 when compared to Tier 2. ***Thus, more than half of the NMHC emissions savings gained under LEV II versus Tier 2 can be attributed to vehicles manufactured to fulfill the ZEV requirement.*** (See Table 15.)

The above analysis underestimates the impact of the ZEV requirement on air quality. First, the ZEV program's requirements for PZEVs and AT-PZEVs require that automakers certify those vehicles to the ultra-low SULEV emissions bin for 150,000 miles useful life, not 120,000. Because emission control systems degrade over time and with wear, the emission reductions generated by vehicles covered by the ZEV mandate will persist for a longer period of time than even conventional LEV II cars.

Second, those rules also require PZEVs and AT-PZEVs to have zero fuel-related evaporative emissions, reducing diurnal-plus-hot-soak NMOG emissions by a further 30 percent for passenger cars and 17 to 23 percent for light-duty trucks from LEV II levels.[45]

In sum, the ZEV requirement, by mandating the sale of significant numbers of ultra-clean vehicles, brings the aggressive emission-reduction goals of the LEV II program within closer technological reach for the rest of the vehicle fleet. And its own particular rules for useful life and evaporative emissions result in additional emission reductions that would not occur were it not for the ZEV requirement.

Toxic Air Pollution Associated With Zero-Emission Vehicles

One argument often lodged against ZEVs – and electric vehicles in particular – is that the pollution caused by power plants that use coal, oil, natural gas or nuclear fuel to generate electricity for vehicles reduces or outweighs the environmental benefits of eliminating emissions from the vehicles themselves.

This argument sets up an unfair comparison with conventional vehicles. The "upstream" pollution caused by petroleum extraction, refining, storage and distribution is rarely factored into the analysis of emissions from internal combustion vehicles. Including oil spills, leaking underground storage tanks, and air emissions from refineries into a calculation of the environmental impacts of internal combustion engines would only serve to underscore the urgency of moving away from fossil fuels for transportation.

Because ZEVs use energy more efficiently than internal combustion engines, their upstream environmental impacts are generally less than those of conventional vehicles. However, in the case of electric vehicles, much depends on the source of electricity in the area in which the vehicles will operate. The approximately 8,000 zero-emission vehicles anticipated to be on the state's roads in 2020 would result in a 0.4 percent increase in demand for electricity in New Hampshire compared to 1999 utility sales figures, should all of them be exclusively powered by electricity.[46]

At present, New Hampshire generates more than 20 percent of its electricity from coal – a notoriously dirty source of power that is responsible for emissions of sulfur dioxide, nitrogen oxides, carbon dioxide and a slew of toxic substances, such as particulate matter and mercury – and 18 percent of its electricity from petroleum.[47] In addition, three power plants – located in Bow, Newington and Portsmouth and owned by Public Service of New Hampshire (PSNH) – rank as the dirtiest in New England and are exempt from meeting modern air pollution standards under the Clean Air Act.[48]

There is reason to believe, however, that electric generation in New Hampshire will be significantly cleaner in 2020 than it is today.

The imposition of tougher air pollution standards and the continued shift toward natural gas for electric generation promise to make electric power plants cleaner on a per-kilowatt-hour basis. There is also the potential for widespread adoption of renewable energy sources – such as solar and wind – for electricity generation.

Moreover, significant public pressure has mounted in recent years to clean up the state's old, dirty fossil fuel-fired power plants, which are exempt from modern pollution controls. These plants pose significant environmental and public health risks and must be required to meet the same clean air standards as modern power plants – regardless of the potential for increased future demand from ZEVs.

The upstream impact of the ZEV requirement will be limited by other factors as well. First, only a small percentage of cars on the road in 2020 will be required to be "pure ZEVs." Should automakers choose to fill the ZEV requirement with PZEVs and AT-PZEVs, they will be able to use a variety of fuels to power them – including compressed natural gas, hybrid-electric motors, and methanol fuel cells – whose emissions would be regulated under LEV II.

Second, there is growing belief that hydrogen fuel cell vehicles – not electric vehicles – will become the "pure" ZEVs of choice within the next two decades. If that were to be the case, the need for off-site generation of electricity to power vehicles would be eliminated entirely, except for any electricity used to extract hydrogen for use as a fuel.

All of these factors serve to minimize the potential long-term pollution displacement effects that would result from the widespread adoption of ZEVs.

Stimulating Technology

The most important benefit of the ZEV program has little to do with reducing emissions in the near term. In its 12 years in existence in California, the ZEV program has proven to be a catalyst for the development of new technologies that could make automobiles even cleaner in the years to come.

The enactment of the original ZEV program in California in 1990 led to an almost immediate spike in interest among automakers in advancing electric vehicle technology. A study conducted for CARB by researchers from the University of California-Davis found that patent applications for electric vehicle-related technologies skyrocketed beginning in 1993 after a long decline during the 1980s and early 1990s.[49] The researchers also found that spending on joint federal government/industry electric vehicle programs increased from $18 million in 1990 to $100 million in 2000.[50]

The renewed research effort had a major impact on the state of electric vehicle technology. Between 1996 and 2000, as a result of California's memorandum of agreement with the automakers, approximately 2,300 electric vehicles of seven different models took the road in California, demonstrating their viability as a transportation alternative.[51]

Other alternative technologies advanced as well. In 1999, Honda offered the first hybrid-electric vehicle, the Insight, for sale in the U.S. The "Big 3" American automakers have been working in conjunction with the federal government on a research effort to develop their own market-ready hybrids by 2003.[52] In 2001, the gasoline-powered California version of the Nissan Sentra became the first vehicle to qualify for PZEV credit. Other vehicles – such as the Honda Accord, Honda Civic GX and Toyota Prius, have achieved SULEV status, one of the main criteria for qualifying as a PZEV.

Hydrogen fuel cells are another technology that has recently made significant advances. Fuel cells use hydrogen to create a chemical reaction that generates electricity to power a vehicle. Fuels such as gasoline and methanol can be used to generate the hydrogen needed, or hydrogen itself can be used as a fuel. When hydrogen is used, the only "emissions" from the fuel cell are water and heat. Other base fuels generate small amounts of hydrocarbon emissions, but produce far less pollution than conventional vehicles because of their superior efficiency.

Until recent years, fuel cells have been mainly used in specialized applications such as space travel. But over the last several years, public-private partnerships at the federal level and in California have worked to bring fuel-cell vehicles to the demonstration stage. The California program, the California Fuel Cell Partnership, aims to put more than 60 fuel cell-powered cars and buses in the state by 2003.[53]

Automakers are already working toward the introduction of fuel-cell vehicles into their fleets, with Ford planning to market such a vehicle beginning in 2004, and other manufacturers planning to follow suit.[54]

The technological state of the art with regard to ZEVs and near-ZEVs is clearly far advanced from where it was when California adopted the ZEV requirement in 1990. Electric vehicles have moved from car-show concepts to daily reality for more than 2,000 Californians. Hybrid and fuel-cell vehicles have gone from the drawing board to concept development to, in the case of hybrids, mass production. California's ZEV requirement has clearly played a role in driving those technological developments.

However the California experience has not only demonstrated the effectiveness of the ZEV requirement in spurring technological innovation, it has also proven the reverse – that without a specific requirement in effect, progress toward advanced technology vehicles will languish.

In 1996, California and the seven major automakers reached an agreement that would lift the ZEV percentage requirement until 2003 in exchange for a commitment by manufacturers to produce a certain number of electric vehicles. The agreement was billed as a way to guarantee that electric cars would make their way onto California's roadways quickly, with the hope that, once established, the vehicles would gain a foothold.

What state officials did not anticipate, however, is that once the agreement expired, automakers would quickly cease producing electric cars – despite evidence of continuing consumer demand.

The decision of the automakers to stop manufacturing electric cars in the absence of a specific government mandate was a setback to the long-term success of the ZEV program. "(C)ontinuity of ZEV production is critical. Market acceptance cannot build, and volume production cannot be achieved, if ZEVs continue to be available only in boom and bust cycles," wrote CARB in a 2000 report.[55] Had CARB maintained some form of ZEV requirement for 1998 through 2003, instead of reaching a voluntary agreement with the automakers, chances are that such a "boom and bust" cycle could have been avoided.

Whether the issue is safety, the adoption of emission control technologies, or the development of advanced technology vehicles, the automobile industry has proven time and time again that it requires a strong push from state and federal agencies before it adopts practices to protect public health and safety. The ZEV requirement, then, is a necessary step to hasten the development of technologies that will make New Hampshire's air cleaner for decades to come.

An Investment Worth Making

The primary argument against the ZEV requirement is that it costs too much. Automakers must spend millions to develop new technologies. And the cars that result are much more expensive than the average consumer can afford.

Because few ZEV or near-ZEV cars have yet made it into general production, there is some truth to this argument. CARB estimates that incremental costs for ZEVs in 2003 will range from $7,500 for city electric vehicles to more than $20,000 for freeway-capable vehicles with advanced batteries.[56] However, CARB noted that if existing electric vehicles were to be produced in volume and if gasoline prices should increase significantly (to $1.75 per gallon), the life-cycle cost of a freeway-capable electric car would begin to approach that of a conventional car.[57] CARB's study also found that hybrid-electric vehicles and PZEV vehicles have significantly lower incremental costs than electric vehicles – approximately $3,200 for hybrids and $200 for PZEVs.[58]

To help with the purchase of ZEVs during the term of the memorandum of agreement, California provided $5,000 per car subsidies to automakers, which then applied the subsidy to their ZEV lease or deducted it from the sticker price.[59] In 2000, California passed a new law under which consumers will be eligible for grants of up to $9,000 toward the purchase of a new ZEV.[60]

There are other costs associated with ZEVs as well. Widespread use of electric vehicles will require some public charging infrastructure to augment charging stations in homes and in offices. Fuel cells that rely on hydrogen as a base fuel will require the availability of hydrogen fueling stations.

But the infrastructure costs – and vehicle costs as well – are offset by the profound environmental and economic benefits that come from a reduced dependence on fossil fuels for transportation use. Subsidizing the development and deployment of advanced technology vehicles is a sound long-term investment to reduce future costs from public health and environmental damage.

Environmentally, in addition to the reductions in emissions noted above, ZEV and near-ZEV vehicles can play a major role in reducing the incentive to drill for oil in sensitive natural areas and eliminate many of the negative "upstream" impacts of oil production, from oil spills to pollution from refineries to leaking underground storage tanks. In addition, the ZEV requirement provides incentives for manufacturers to meet higher energy-efficiency standards for zero-emission vehicles and AT-PZEVs, which can not only ease demand for oil or electricity but can also reduce emissions of greenhouse gases responsible for global warming.

The global warming benefits of the ZEV program alone make it worth consideration. In 2001, Gov. Jeanne Shaheen, along with other New England governors and eastern Canadian premiers, committed to a Climate Change Action Plan that seeks to reduce regional greenhouse gas emissions to 1990 levels by 2010. The plan included a recommendation to "promote the shift to higher-efficiency vehicles, lower carbon fuels and advanced technologies."[61]

An analysis produced for CARB's 2000 biennial review of the ZEV program found that electric and hybrid-electric vehicles produced the lowest emissions of carbon dioxide among seven vehicle-fuel combinations studied.[62] Another analysis, by Argonne National Laboratory, found that battery-electric passenger cars receiving their power from Northeastern power sources have 43 percent lower greenhouse gas emissions over the entire fuel cycle than conventional cars. Hybrid-electric vehicles have 46 percent lower greenhouse gas emissions and compressed natural gas vehicles 11 percent lower emissions over their fuel cycles than conventional cars.[63] With the number of vehicle miles traveled expected to increase in New Hampshire and elsewhere, the introduction of significant numbers of alternative vehicles will be needed to prevent further increases in carbon emissions from the light-duty fleet – let alone meet the regional greenhouse gas reduction goals set in the Climate Change Action Plan.

Economically, the introduction of ZEVs would cushion the economy from the impact of intermittent oil-price shocks, reduce dependence on foreign oil, and safeguard New Hampshire from severe social disruption should the oil supply become significantly strained within the next two decades, as some experts predict. The development and production of ZEVs can also help spur the economy, provided that the United States acts aggressively to take leadership in this emerging market. New Hampshire, with its growing concentration of high-tech industries, is well-suited to enjoy the benefits of this technological shift.

Finally, the adoption of the ZEV requirement can help hasten the development of alternative fuel sources for other uses – from home heating to manufacturing – bringing added stability and efficiency to those sectors as well.

These benefits more than justify the financial and regulatory investment that would be made by adoption of the ZEV requirement in New Hampshire.

A Role for New Hampshire

New Hampshire's adoption of LEV II and the ZEV requirement would not, in and of itself, bring about the massive technological shift described above. However, the state has a key role to play in making such a shift happen.

While New Hampshire makes up only a small percentage of the light-duty cars and trucks registered in the United States, it is also the only northern New England state not to have adopted at least part of the LEV II program. With New York, Massachusetts and Vermont already planning to require the sale of ZEVs within the next five years, New Hampshire could help form a core northeastern block of states committed to the program. That could create a powerful incentive for other nearby states to join the program and establish New England as a center for the development of ZEV technology. It would also guarantee New Hampshire residents access to the cleanest cars available – cars that will already be on sale to residents of neighboring states.

In short, despite its small size, New Hampshire is uniquely situated to adopt a policy that would not only reap major benefits for its own citizens, but help build the solid, sustainable base of demand that will be required for ZEVs to become an economically viable alternative in the years to come.

6. Policy Recommendations

New Hampshire should join Massachusetts, New York and Vermont in adopting the California Low-Emission Vehicle II standards.

Adoption of the California LEV II standards and the ZEV requirement is one of the most effective steps New Hampshire can take to protect citizens from the health dangers posed by air toxics, reduce the emission of smog-forming pollutants, attain the state's goals for reducing greenhouse gas emissions, and strengthen the state's long-term economic and environmental security.

Northeast States for Coordinated Air Use Management (NESCAUM) has estimated the changes in ambient air toxics concentrations for the northeastern states that would take place under all current and proposed federal mobile source regulations – including Tier 2. NESCAUM concluded that all those regulations, combined, would fail to meet standards for cancer risk set out by the Clean Air Act by 2030.

Adoption of the LEV II standards is a straightforward and effective way that New Hampshire can move itself closer to the goal of reducing the cancer threats posed by air toxics.

New Hampshire should consider other incentives for ZEV development and use.

Even under the LEV II program, it will be several years before New Hampshire residents have the opportunity to purchase or own a ZEV or near-ZEV vehicle. There are several ways the state can encourage the speedy introduction of ultra-clean vehicles.

- **Direct subsidies or tax credits for consumers.** These should be carefully targeted to encourage only the purchase of vehicles with true environmental benefits: electric and fuel-cell vehicles, vehicles dedicated to run on natural gas or other clean fuels, and hybrid electric vehicles with high fuel efficiency. Tax credits that are combined with increased taxes on gas guzzlers would be a revenue-neutral way to encourage purchase of cleaner cars.
- **Requirements that government or public agencies purchase zero emission and alternative fuel vehicles for appropriate uses.** The state of New Hampshire deserves credit for purchasing a small number of electric, compressed natural gas and hybrid-electric vehicles for government use. These procurement efforts should continue at the state level and the state should identify ways to assist local and county governments in making similar purchases. Public-private efforts such as the Granite State Clean Cities Coalition can also play a useful role in expanding the use of alternative-fuel vehicles.
- **Encouragement of voluntary labeling systems that can help environmentally conscious consumers identify the cleanest cars.** The recently announced Granite State Clean Cars initiative, while laudable in its intent, sets the bar too low for inclusion, allowing vehicles certified to NLEV standards to bear the Granite State Clean Cars sticker. Limiting inclusion to the program to vehicles that qualify as California ULEVs and SULEVs and obtain truly exceptional fuel economy – or providing more detailed emissions information on all vehicles to consumers at the point of sale – could help New Hampshire consumers better identify which vehicle purchases will result in truly substantial benefits to air quality.
- **Providing assistance for the development of charging infrastructure for electric vehicles or other infrastructure improvements.**

We acknowledge that it may be politically difficult with the recent economic downturn to create new incentives such as direct subsidies. But it is important for state officials to realize that a thoughtful and effective approach to the introduction of ZEVs will require carrots as well as sticks. The experience of California and other states should help state officials decide what works and what doesn't in encouraging ZEV use.

Adopt Other Policies to Reduce Emissions of Toxic Substances into New Hampshire's Air

Light-duty cars and trucks make up a significant portion of air toxics releases in New Hampshire. But other state and federal policies will likely also be needed to fully protect state residents from the dangers posed by air toxics. Strengthening the U.S. EPA's Mobile Source Air Toxics rule and moving to require the state's old, fossil fuel-fired power plants to meet modern air pollution standards are among the steps that can be taken to complement the reductions in air toxics emissions that would result from adoption of the LEV II standards.

APPENDIX A: METHODOLOGY AND SOURCES

Assumptions

This report is intended to calculate an estimate of anticipated reductions in toxic air pollution that would take place annually in New Hampshire beginning in 2020 under the LEV II standards as opposed to federal Tier 2 emission controls. Estimates of these relative benefits – as well as other conclusions reached by this report – were derived using a simplified methodology that does not reflect all local factors that can influence vehicle emissions. It is intended as a measure of the relative policy implications of the LEV II and Tier 2 standards, not a projection of future toxic pollution in New Hampshire.

Two assumptions underlie this analysis:

- **This study focused on emissions from light-duty vehicles only.** New standards for medium-duty passenger vehicles are part of the updated Tier 2 and LEV II rules. However, the rules still primarily focus on light-duty vehicles, which make up the vast majority of vehicle miles traveled in the U.S. As a result, this analysis understates the relative emissions benefits of both the Tier 2 and LEV II programs.
- **This study assumes that no light-duty vehicles are powered by diesel.** This assumption is largely true at present, because diesel-powered vehicles make up less than one percent of overall car and light truck sales. However, as noted earlier, the EPA projects that light-duty diesel vehicles could increase to as much as 9 percent of all new car sales and 24 percent of all light truck sales by 2015 under one scenario.

  Because these projections of future diesel penetration of the light-duty fleet are highly speculative – and because the use of diesel fuel results in a different mix of air toxics emissions than gasoline, introducing a complicating factor to the analysis – this study assumed that the light-duty fleet on the road in 2020 will continue to be gasoline-powered vehicles.

Emissions Estimation

Overall NMHC Emissions

Estimates of relative reductions in non-methane hydrocarbon (NMHC) emissions are based on emissions factors calculated by Cambridge Systematics in their analysis for the Massachusetts DEP, which were in turn derived from EPA's Tier 2 and MOBILE5b models. These emission factors have the limitation of being based on climactic and driving patterns that differ slightly from those in New Hampshire. It is also based on the assumptions (true in Massachusetts) a) that LEV II standards will be implemented beginning in 2004, not 2006 as would be the case in New Hampshire, and b) that the LEV I program, rather than the NLEV and Tier 1 programs, was in effect for vehicles sold prior to the 2004 model year. As a result, the Mass. Emissions Factor model will tend to slightly exaggerate the differences between LEV II and Tier 2 when applied to New Hampshire. Finally, the EPA has recently issued a new emissions modeling program – MOBILE6 – that supersedes MOBILE5b and the Tier 2 model. MOBILE6 was made public in late January, just as this analysis was being completed, and there was not time to revisit the analysis based on the new model.

Overall emissions were calculated by multiplying the total light-duty VMT projected for 2020 for each vehicle class (as derived below) by the applicable emission factor for that class.

Air Toxics

Estimated emissions of individual air toxics were calculated by converting total estimated NMHC emissions into estimated NMOG emissions, then multiplying by speciation percentages in EPA's Speciate database. The speciation profiles chosen were profile #1313 for tailpipe emissions and profile #1305 for evaporative emissions. Both profiles are based on 1990 baseline gasoline. No attempt was made to account for differences in speciation profiles based on the use of oxygenated or reformulated gasoline.

In both profiles, the total organic gas (TOG) percentages in the EPA's speciation model were converted to NMOG by eliminating the methane portion of the profile. In addition, the profiles were used to estimate an NMHC to NMOG conversion factor based on the percentage of TOG represented by non-hydrocarbon organic gases (alcohols, ethers, ketones and aldehydes). This factor was 1.027 for exhaust and 1.030 for evaporative emissions. NMHC emissions were multiplied by the conversion factor, and then by the percentages in the NMOG portion of the speciation profile to derive individual air toxics emissions.

Volatile Organic Chemicals

Speciation profiles were also employed to derive a NMOG to VOC conversion factor, by calculating the percentage of NMOG represented by compounds exempted by the EPA from its definition of VOCs per Code of Federal Regulations 40 CFR 51.100(s)(1). This factor was found to be 0.971 for exhaust and 1.0 for evaporative emissions. The factor was then multiplied by total NMOG emissions to derive total VOC emissions.

Number of Cars Taken Off the Road

An estimate was made of the number of 2000 model year cars that would be taken off the road to equal the additional air toxics pollution reductions in LEV II over Tier 2.The "car" used for this comparison is an average passenger car on the road in 2000 per the emission factors in Cambridge Systematics' analysis. The per-mile emission levels were then multiplied by the estimated number of vehicle-miles traveled by a light-duty car in 2020 per the methodology below, and then the chemical speciation profiles listed above, to arrive at a per-car amount of air toxics emissions. The total air toxics reductions under LEV II were then divided by this per-car amount to arrive at the number of cars that would be taken off the road.

Fleet Characteristics and Vehicle Miles Traveled

Unless otherwise noted, fleet and vehicle miles traveled data attributed to the EPA are from "Fleet Characterization Data for MOBILE6: Development and Use of Age Distributions, Average Annual Mileage Accumulation Rates and Projected Vehicle Counts for Use in MOBILE6," published April 1999.

The total number of light-duty vehicles in use in 2020 in the state was determined by taking the national in-use vehicle fleet estimates from EPA and multiplying them by the percentage of car and truck registrations for the state in 2000 per Ward's Automotive Yearbook 2001. The number of light-duty trucks in each class was determined by multiplying the total number of light-duty trucks by ratios of truck classes established by EPA for MOBILE6.

Vehicle counts were further broken down by model year using age distribution percentages for each vehicle class established by EPA.

Vehicle miles traveled data are based on the estimate of 47-state VMT for 2020 prepared by EPA corrected to take account for VMT in Alaska, California and Hawaii. Total VMT was then disaggregated into national VMT by vehicle subgroupings (LDV, LDT1/2 and LDT3/4) using ratios in worksheet T2MODAQA of EPA's Tier 2 model, and further broken down into individual vehicle classes using the vehicle stock splits in EPA's MOBILE6 fleet characterization data.

Two correction factors were applied to determine what portion of VMT should be applied to vehicles of each model year and to account for different driving habits at the state versus national level.

A vehicle age factor was applied consisting of the vehicle mileage accumulation rates developed by EPA divided by the average VMT per vehicle for 1996 per Ward's Automotive Yearbook 2001.

A state correction factor was applied consisting of the average VMT per vehicle for the state in 1999 divided by the national average VMT for 1999 (per Ward's and the "Highway Statistics 1999" published by the U.S. Department of Transportation).

The result was a state-specific estimate of the number of miles traveled per vehicle by vehicles in each class and each model year for the year 2020. This number was then multiplied by the estimated fleet composition numbers to arrive at the total number of VMT traveled by vehicles in each class and each model year during 2020.

ZEV Program Analysis

Because the emission factors generated from the Massachusetts DEP modeling encompass the overall impact of the LEV II rules, a separate model was constructed to estimate the relative impact of the ZEV requirement within the LEV II program. This model was used to project the contribution made by the ZEV program to overall LEV II emissions reductions, the amount of air toxics released by power plants to fuel ZEVs, and the additional evaporative emissions benefits of the "zero" evaporative emission standard in the ZEV program.

Estimates of tailpipe emissions for ZEV-compliant vehicles were obtained by multiplying the estimated VMT of vehicles in each model year and class in 2020 by the applicable emission standard. A similar calculation was performed for Tier 2 vehicles, multiplying VMT by Cambridge Systematics' inference of grams/mile NMOG emissions based on 120,000 miles useful life, in its analysis for the Massachusetts DEP. This method will tend to underestimate emissions from both ZEV-compliant and Tier 2 vehicles.

Estimates of the amount of electric power needed to operate ZEVs were derived by multiplying the average VMT per LDV in 2020 by the number of ZEVs on the road that year (as calculated based on CARB's projection of how automakers will implement the ZEV requirement) and an estimated average energy efficiency of 0.5 kW per mile per CARB's 2000 ZEV biennial review. Per-kilowatt-hour toxic emissions levels were derived by taking the total toxic emissions for electric power plants in the state from the 1999 EPA Toxics Release Inventory and dividing that number by the number of kilowatt-hours of electricity sold in the state in 1999 per the Energy Information Administration's Annual Electric Utility Report. Total electricity consumption of ZEVs on the road in the state in 2020 was then multiplied by the per-kilowatt-hour toxic emissions data to arrive at the amount of toxic pollution from power plants resulting from ZEVs.

APPENDIX B: GLOSSARY OF ABBREVIATIONS

ALVW – Adjusted loaded vehicle weight (average of gross vehicle weight and actual vehicle weight).

AT-PZEV – Advanced technology partial zero-emission vehicle. Class of ultra-clean vehicles under California standards that run on alternative fuels.

CARB – California Air Resources Board.

CO – Carbon monoxide.

DEP – Massachusetts Department of Environmental Protection.

GVW – Gross vehicle weight (maximum design loaded weight).

HAP – Hazardous air pollutant. Also known as air toxics.

HLDT – Heavy light-duty truck.

I/M – Inspection and maintenance programs.

LDV – Light-duty vehicle (i.e. passenger car).

LDT – Light-duty truck.

LEV – Low-Emission Vehicle program adopted in California in 1990. Also, the dirtiest bin to which vehicles may be certified under the LEV II standards.

LEV II – Low-Emission Vehicle program adopted in California in 1999.

LLDT – Light light-duty truck.

LVW – Loaded vehicle weight (vehicle weight plus 300 pounds).

MDPV – Medium-duty passenger vehicle.

NLEV – National Low-Emission Vehicle program adopted as a result of voluntary agreement between automakers, state governments and the EPA.

NMHC – Non-methane hydrocarbons. Category of emissions that includes many air toxics. Includes most of the NMOG category, but not aldehydes, ketones, alcohols and ethers

NMOG – Non-methane organic gas. Category of emissions that includes many air toxics. Includes non-methane hydrocarbons and other organic gases such as aldehydes, ketones alcohols and ethers.

NOx – Nitrogen oxides, a major precursor of smog.

OTC – Ozone Transport Commission. A group of northeastern states formed by Clean Air Act of 1990 to promote coordinated smog-reduction policies.

PC – Passenger car.

PM – Particulate matter, a toxic air pollutant.

PZEV – Partial zero-emission vehicle. Class of ultra-clean vehicles under California standards that may include vehicles run by internal combustion or other engines.

SULEV – Super low-emission vehicle. A certification bin under the LEV II standards that is cleaner than ULEV but not as clean as ZEV. AT-PZEVs and PZEVs must meet SULEV emission standards.

ULEV – Ultra-low-emission vehicle. A certification bin under the LEV II standards that is cleaner than LEV but not as clean as SULEV.

VOC – Volatile organic compounds. Organic compounds that evaporate into the air. Includes many air toxics.

VMT – Vehicle miles traveled.

ZEV – Zero-emission vehicle.

APPENDIX C: CONCENTRATIONS OF AIR TOXICS IN NEW HAMPSHIRE

Table C-1: County Rankings for Ambient Concentrations of Selected Air Toxics from On-Road Mobile Sources

	1,3 Butadiene		Formaldehyde		Benzene		Acetaldehyde		
County	Ambient Concentration	State Rank	Ambient Concentration	State Rank	Ambient Concentration	State Rank	Ambient Concentration	State Rank	Average Rank
Hillsborough	0.050	1	0.453	1	0.577	1	0.399	1	1.0
Rockingham	0.025	2	0.319	2	0.359	2	0.306	2	2.0
Strafford	0.021	3	0.191	3	0.240	3	0.177	3	3.0
Merrimack	0.012	6	0.163	4	0.168	4	0.160	4	4.5
Belknap	0.014	5	0.102	5	0.140	5	0.096	5	5.0
Cheshire	0.014	4	0.100	6	0.138	6	0.091	6	5.5
Sullivan	0.008	7	0.068	7	0.088	7	0.069	7	7.0
Grafton	0.006	8	0.049	8	0.065	8	0.047	8	8.0
Carroll	0.004	10	0.042	9	0.049	9	0.042	9	9.3
Coos	0.005	9	0.026	10	0.043	10	0.021	10	9.8

Table C-2: Formaldehyde: Ambient Concentrations in New Hampshire Counties

County	Total Ambient Concentration (μg/m³)	Ambient Concentration from On-Road Mobile Sources (μg/m³)	% from On-Road Mobile Sources	Factor by which Total Ambient Concentration Exceeds EPA Health Standards	Rank for Total Ambient Concentration
Belknap	0.63	0.102	16%	8.1	5
Carroll	0.46	0.042	9%	6.0	10
Cheshire	0.57	0.100	18%	7.4	6
Coos	0.52	0.026	5%	6.8	8
Grafton	0.49	0.049	10%	6.4	9
Hillsborough	1.09	0.453	42%	14.1	1
Merrimack	0.65	0.163	25%	8.5	3
Rockingham	0.89	0.319	36%	11.6	2
Strafford	0.64	0.191	30%	8.3	4
Sullivan	0.53	0.068	13%	6.8	7

Table C-3: Benzene: Ambient Concentrations in New Hampshire Counties

County	Total Ambient Concentration (µg/m³)	Ambient Concentration from On-Road Mobile Sources (µg/m³)	% from On-Road Mobile Sources	Factor by which Total Ambient Concentration Exceeds EPA Health Standards	Rank for Total Ambient Concentration
Belknap	1.26	0.140	11%	9.7	2
Carroll	0.91	0.049	5%	7.0	5
Cheshire	0.73	0.138	19%	5.7	9
Coos	0.65	0.043	7%	5.0	10
Grafton	0.84	0.065	8%	6.4	7
Hillsborough	1.34	0.577	43%	10.3	1
Merrimack	0.91	0.168	18%	7.0	4
Rockingham	1.16	0.359	31%	8.9	3
Strafford	0.90	0.240	27%	6.9	6
Sullivan	0.77	0.088	11%	5.9	8

Table C-4: 1,3-Butadiene: Ambient Concentrations in New Hampshire Counties

County	Total Ambient Concentration (µg/m³)	Ambient Concentration from On-Road Mobile Sources (µg/m³)	% from On-Road Mobile Sources	Factor by which Total Ambient Concentration Exceeds EPA Health Standards	Rank for Total Ambient Concentration
Belknap	0.064	0.014	22%	17.7	2
Carroll	0.032	0.004	13%	8.9	4
Cheshire	0.029	0.014	49%	8.1	8
Coos	0.032	0.005	17%	8.8	5
Grafton	0.031	0.006	21%	8.5	7
Hillsborough	0.071	0.050	70%	19.8	1
Merrimack	0.029	0.012	41%	7.9	9
Rockingham	0.043	0.025	58%	12.0	3
Strafford	0.031	0.021	66%	8.7	6
Sullivan	0.026	0.008	30%	7.3	10

Table C-5: Acetaldehyde: Ambient Concentrations in New Hampshire Counties

County	Total Ambient Concentration (µg/m³)	Ambient Concentration from On-Road Mobile Sources (µg/m³)	% from On-Road Mobile Sources	Factor by which Total Ambient Concentration Exceeds EPA Health Standards	Rank for Total Ambient Concentration
Belknap	0.200	0.096	48%	0.4	5
Carroll	0.095	0.042	44%	0.2	9
Cheshire	0.166	0.091	55%	0.4	6
Coos	0.068	0.021	31%	0.2	10
Grafton	0.104	0.047	45%	0.2	8
Hillsborough	0.581	0.399	69%	1.3	1
Merrimack	0.250	0.160	64%	0.6	4
Rockingham	0.481	0.306	64%	1.1	2
Strafford	0.263	0.177	67%	0.6	3
Sullivan	0.135	0.069	51%	0.3	7

Appendix D: EPA List of Regulated Mobile Source Air Toxics

Acetaldehyde
MTBE
Acrolein
Ethylbenzene
Naphthalene
Arsenic Compounds
Formaldehyde
Nickel Compounds
Benzene
n-Hexane
Polycyclic Organic Matter[i]
1,3-Butadiene
Lead Compounds
Styrene
Chromium Compounds
Manganese Compounds
Toluene
Dioxin/Furans
Mercury Compounds
Xylene

[i] Polycyclic Organic Matter includes organic compounds with more than one benzene ring, and which have a boiling point greater than or equal to 100 degrees centigrade. A group of seven polynuclear aromatic hydrocarbons, which have been identified by EPA as probable human carcinogens.

Source: Federal Register: March 29, 2001 (Volume 66, Number 61), pages 17229-17273.

Appendix E: Emission Factors for Tailpipe and Evaporative NMHC Emissions

Cumulative fleet emission factors for tailpipe and evaporative NMHC emissions in 2020 in grams/mile.

	Tier 2		LEV II	
	Tailpipe	Evaporative	Tailpipe	Evaporative
LDV	0.097	0.119	0.059	0.102
LDT 1/2	0.107	0.110	0.076	0.099
LDT 3/4	0.211	0.132	0.180	0.121

Source: "Background Document and Technical Support for Public Hearings on the Proposed Amendments to the State Implementation Plan for Ozone and Public Hearing and Findings Under the Massachusetts Low Emission Vehicle Statute," Massachusetts Department of Environmental Protection, October 1999.

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16. Walsh, pages 28-29.
17. Federal Register, Vol. 65, No. 28, 10 February 2000, page 6855.
18. Walsh, page 9. The LEV II NMOG fleet averages are measured at 50,000 miles rather than 120,000 miles useful life.
19. Walsh, page 7.
20. LEV II allows manufacturers to certify up to four percent of their heavy (California LDT2) fleet to a higher NOx standard of 0.10 g/mi.
21. From VMT fractions included in EPA's Tier 2 model, spreadsheet T2MODAQA.XLS.
22. Walsh, page 18.

23. Massachusetts Department of Environmental Protection, "Background Document and Technical Support for Public Hearings on the Proposed Amendments to the State Implementation Plan for Ozone and Public Hearing and Findings Under the Massachusetts Low Emission Vehicle Statute," October 1999.

24. New York State Department of Environmental Conservation, "Regulatory Impact Statement Summary," Amendments to 6 NYCRR Part 218 , 2000, page 4.

25. Walsh, page 37.

26. Walsh, page 18, 31.

27. The chemical composition of vehicle exhaust varies greatly depending on the vehicle and the type of fuel used. The speciation profiles used in this analysis are based on 1990 baseline gasoline and do not account for the use of oxygenated or reformulated gasoline. The results presented here are intended to be suggestive of the air toxics reductions that could be expected under LEV II.

28. Estimate of "average car" toxic emissions based on applying speciation profile to a typical light-duty vehicle on the road in 2000 whose emissions were calculated using 2020 vehicle-miles traveled estimates.

29. U.S. Environmental Protection Agency, "Tier 2/Sulfur Regulatory Impact Analysis," December 1999, page III-36.

30. U.S. Environmental Protection Agency, "Tier 2/Sulfur Regulatory Impact Analysis," December 1999, page III-39.

31. The NMOG standards for the ULEV bin under LEV I are 0.055 g/mi for LDVs and LDT1s; 0.07 for LDT2s; 0.143 for LDT3s; and 0.167 for LDT4s, compared to an anticipated fleet average under Tier 2 of 0.09 g/mi. The NOx standards are 0.3 g/mi for LDVs and LDT1s; 0.5 for LDT2s; 0.6 for LDT3s; and 0.9 for LDT4s, compared with the 0.07 g/mi fleet average standard under Tier 2. From Walsh, 5-6.

32. California Air Resources Board, "Staff Report: Initial Statement of Reasons: Proposed Amendments to California Exhaust and Evaporative Emission Standards and Test Procedures for Passenger Cars, Light-Duty Trucks and Medium-Duty Vehicles," 18 September 2001, II-55.

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38. State of New York, "Governor: Regulation to Reduce Harmful Vehicle Emissions," press release, 4 January 2002.

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40. In this case, "zero" evaporative emissions refers to emissions from fuel. Hydrocarbon evaporative emissions also come from other sources, including paint, adhesives, air conditioning refrigerants, vinyl, tires, etc. Passenger cars releasing less than 0.35 grams/test, LLDTs releasing less than 0.65 grams/test, and HLDTs releasing less than 0.9 grams/test in evaporative emissions meet the "zero" evaporative emission requirement under California standards. Sources: California Air Resources Board, "California Evaporative Emission Test Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles," I.E.1(2), adopted 5 August 1999. Harold M. Haskew et al, "Running Loss Emissions from In-Use Vehicles," Coordinating Research Council, February 1999, 3.

41. California Air Resources Board , "Zero Emission Vehicle Program Changes," Fact Sheet, 23 February 2001.

42. Based on California Air Resources Board, "Fleet Implementation Schedule," downloaded from http://www.arb.ca.gov/regact/zev2001/zev2001.htm, 27 December 2001. Percentages of ZEV. AT-PZEV and PZEV vehicles in use for each model year based on CARB's estimate of total number of ZEV-compliant vehicles

sold in each model year divided by total sales base covered by the ZEV requirement in each model year. This percentage is then applied to the fleet composition projection derived from the methodology outlined in Appendix A. Note: CARB assumes that even though LDT2-4s are counted toward the ZEV requirement beginning in 2007, manufacturers will choose to comply with the requirement by selling additional numbers of ZEV-compliant LDVs and LDT1s. The remainder of this section assumes that this assumption is true.

43. The model used to calculate emissions from ZEV program-compliant and Tier 2 vehicles differs from the model used in the rest of this report in that it is based on compliance with emission standards and not the results of emission factor modeling. Because a large proportion of real-world hydrocarbon emissions come from vehicles that, due to age or malfunction, do not meet established standards, this method will tend to significantly underestimate actual emissions from both ZEV-compliant and Tier 2 vehicles. However, because ZEV-compliant vehicles must have their emissions certified for a longer useful life (150,000 miles as opposed to 120,000 miles under Tier 2), and because a significant number of those vehicles will likely be powered by fuel sources (such as electricity and fuel cells) that are not subject to the effects of fuel or emission system degradation, it is more likely that ZEV-compliant vehicles will comply with emission standards over the long haul. Thus, this method – while not an accurate representation of real-world conditions – likely provides a fair portrayal of the role of the ZEV program in overall emission reductions under LEV II, and may even underestimate that role. Note: because this analysis is based on certification standards communicated in NMOG, that measure is used here and subsequently in this section of the report.

44. Values of ZEV and Tier 2 emissions calculated in terms of NMOG.

45. Based on maximum non-fuel evaporative emissions of 0.35 grams per test for passenger cars, 0.50 grams per test for light-duty trucks 6,000 lbs. GVW and under, and 0.75 grams per test for light-duty trucks from 6,001 to 8,500 lbs. Source: California Code of Regulations, title 13, section 1976(b)(1)(E).

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Fact Sheet
California Environmental Protection Agency
Air Resources Board

California's Zero Emission Vehicle Program - 2003

In 1990, California embarked on a plan to reduce vehicle emissions to zero through the introduction of the Zero Emission Vehicle (ZEV) Program. At that time, the Air Resources Board (ARB) required that in 1998, 2% of the vehicles produced for sale in California had to be ZEVs, increasing to 5% in 2001 and 10 percent in 2003.

The ZEV mandate was adjusted in 1996 to eliminate the "ramp up" years but left in place the 10 percent ZEV requirement for 2003, and in 1998 to allow partial ZEV (PZEV) credits for extremely clean vehicles that were not pure ZEVs. The underlying goal, however, never changed. California remained committed to seeing increasing numbers of ZEVs in the vehicle fleet. The challenge was determining how to reach this goal.

In January 2001 the Board once again considered the status of the ZEV program leading to more proposed modifications. The challenge at that time was to maintain progress towards commercialization of ZEVs, while recognizing constraints due to cost, lead-time, and technical challenges. The 2001 modifications allowed large manufacturers to meet their ZEV requirement with the following mix of vehicles.

Requirement	Category	Description
2% Gold	Pure ZEVs	Battery EVs or hydrogen fuel cells; zero tailpipe emissions.
2% Silver	Advanced technology PZEVs (AT PZEVs)	These vehicles have extremely low (PZEV) emission levels and also employ ZEV-enabling technologies such as electric drive.
6% Bronze	Partial Zero Emission Vehicles (PZEVs)	These vehicles have tailpipe emission levels similar to the power plant emissions from ZEVs.

In June 2002, due to a lawsuit filed against the ARB, a federal district judge issued a preliminary injunction that prohibited the ARB from enforcing the 2001 ZEV amendments with respect to the sale of new motor vehicles in model years 2003 or 2004. The lawsuit was focused on the assertion that AT PZEV provisions pertaining to the fuel economy of hybrid electric vehicles were preempted by the Energy Policy and Conservation Act of 1975 - the law directing the National Highway Traffic Safety Administration to establish corporate average fuel economy (CAFE) standards. Since adopting the 2003 Amendments to the ZEV regulation, the parties to the lawsuits have agreed to end the litigation.

Although some may question the benefits or success of the ZEV regulation - it has been a huge success for California's air quality. The major automakers placed over 4,000 battery-powered ZEVs in California's between 1998 and 2003. Consumers quickly bought these highly functional vehicles and called for more. The regulation also spurred advances in natural gas and other alternative fueled vehicles, super-clean gasoline vehicles, fuel-efficient hybrids that are powered by a combination of electric motors and internal combustion engines, and fuel cell vehicles powered by electricity created from pollution-free hydrogen. We are seeing large numbers of PZEVs on the road and expect many more PZEVs and AT PZEVs in the years to come.

2003 Modifications

In order to address the preliminary injunction and better align the program requirements with the status of technology development, staff proposed additional modifications to the ZEV regulation in March 2003. After hearing extensive testimony and public comment, the Board adopted changes to the ZEV program on April 24, 2003. Here are the significant features of the April 2003 changes to the ZEV regulation:

- The ZEV percentage requirements will restart in the 2005 model year, while allowing manufacturers to earn and bank credits for vehicles produced prior to the 2005 model year.

- The way that credits from ZEVs are calculated is revised to remove the efficiency multiplier and specify the number of credits earned each model year by each of the following five "types" of pure ZEVs.

Vehicle Type	Example
NEVs	Low speed "Neighborhood Electric Vehicles"
Type 0	Utility low-range battery electric vehicles
Type I	Mid-range "city electric vehicles"
Type II	Full function battery electric vehicles
Type III	Fuel cell vehicles

- The ATPZEV calculation methods are amended to remove all references to fuel economy or efficiency. In addition, the criteria for determining if a hybrid electric vehicle (HEV) earns advanced ZEV componentry allowances were changed so that a hybrid-electric PZEV would have to exhibit traction drive boost, regenerative braking and idle start/stop in order to qualify at one of the three levels described in the table below.

Level	Description	AT PZEV Credits
Level 1: Low voltage, low power	Less than 60 volts and at least four kilowatt (kW) motor power	0.2 credits through model-year 2008
Level 2: High voltage	60 volts or more and minimum 10 kW motor power	0.4 credits, reduced in stages in the 2012 and 2015 model years to 0.25
Level 3: High voltage, high power	60 volts or more and minimum 50 kW motor power	0.5 credits, reduced in stages in the 2012 and 2015 model years to 0.35

- Large volume manufacturers will be allowed to comply with either a "base compliance path" using percentage ZEV requirements structured like those in the 2001 ZEV amendments, or with an "alternative compliance path." The "alternative compliance path" allows AT PZEVs to be used to meet pure ZEV obligations, provided that the manufacturer meets the requirements specified in the table below.

Model Years	Manufacturer's Market Share of
2001-2008	250 fuel cell vehicles
2009-2011	2,500 fuel cell vehicles
2012-2014	25,000 fuel cell vehicles
2015-2017	50,000 fuel cell vehicles

- An independent expert review panel will be established to advise the Board on technology advances made in pure ZEV and AT PZEV technologies, in order for the Board to consider changes to the requirements for the 2009 and subsequent model years.

Where can I get more information?

Please contact the ARB toll-free at (800) END-SMOG/(800) 363-7664 (California only) or (800) 272-4572. For information on the ARB's ZEV Program, visit www.DriveClean.ca.gov or www.arb.ca.gov. You may obtain this document in an alternative format by contacting ARB's Americans with Disabilities Act Coordinator at (916) 322-4505 (voice); (916) 324-9531 (TDD, Sacramento only); or (800) 700-8326 (TDD, outside Sacramento).

Fact Sheet

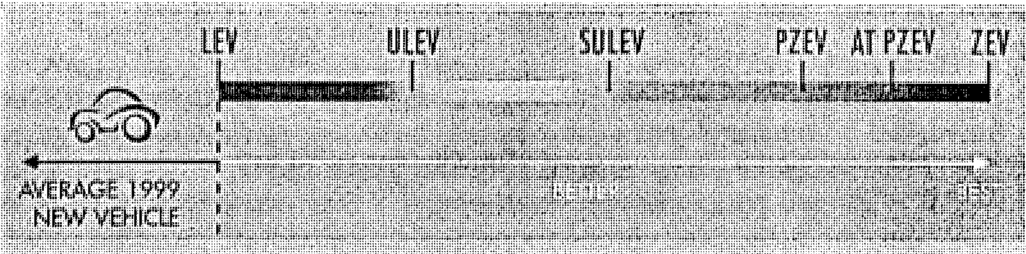
California Environmental Protection Agency
Air Resources Board

California Vehicle Emissions

A vehicle's emissions are the result of the combined attributes of fuel type, controls on the engine's operations, and maintenance throughout the life of the vehicle. All new vehicles sold in California must be certified to one of six California Air Resources Board (ARB) emissions ratings. A vehicle's rating is posted on the Vehicle Emissions Control Information Label found under the hood, and it is the only true indicator of a new car's overall emissions.

2004 California Vehicle Emissions

California's emissions ratings apply to all new vehicles sold in this state, and are the most stringent in the world.



LEV *(Low Emission Vehicle)*: The least stringent emission standard for all new cars sold in California beyond 2004.

ULEV *(Ultra Low Emission Vehicle)*: 50% cleaner than the average new 2003 model year vehicle.

SULEV *(Super Ultra Low Emission Vehicle)*: 90% cleaner than the average new 2003 model year vehicle.

PZEV *(Partial Zero Emission Vehicle)*: Meets SULEV tailpipe standards, has a 15-year / 150,000 mile warranty, and zero evaporative emissions[1].

AT PZEV *(Advanced Technology PZEV)*: Meets PZEV standards and includes ZEV enabling technology.

ZEV *(Zero Emission Vehicle)*: Zero tailpipe emissions, and 98% cleaner than the average new 2003 model year vehicle.

How Technologies Compare in Emissions

Gasoline Powered Vehicles: Gasoline powered vehicles have historically been considered very polluting, however, recent model years have achieved very stringent emissions standards. In 2004, 37 gas-powered vehicle models were certified to PZEV standards, and this number is expected to increase greatly in coming years. Gas-powered vehicles are able to achieve stringent standards because of advanced controls on engines and fuel systems that substantially reduce tailpipe emissions and virtually eliminate evaporative emissions.

Hybrid-Electric Cars: Hybrid vehicles will always produce fewer greenhouse gas emissions than a comparable pure gasoline powered vehicle. The overall emissions, however, will vary depending on the vehicle's "level of hybrid" (electrical storage capacity), and how advanced the engine

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[1] *Evaporative emissions are fuel vapors that escape to the outside*

controls are. Each hybrid model must be judged individually, and may or may not have fewer smog-forming emissions than a gas-powered car.

Alternative Fueled Vehicles (AFVs): AFVs can operate on fuel other than gasoline or petroleum based diesel, such as biologically produced diesel (biodiesel), electricity, ethanol, hydrogen (H_2), methanol, natural gas (CNG), or propane (LPG). Alternative fuels are generally cleaner than gasoline, but adequate controls on the engine are necessary to ensure fewer overall emissions.

- ***Flex-fuel*** – A flexible fueled vehicle has a single fuel tank, fuel system, and engine. The vehicle is designed to run on unleaded gasoline and an alcohol fuel (usually ethanol) in any mixture. These engines have sensors to analyze the fuel mixture, and adjust the fuel injection and timing. Since fuel composition and engine controls vary widely from one car to the next, flex-fuel vehicles do not assure fewer emissions than dedicated gas-powered vehicles.

- ***Bi-fuel*** – A bi-fuel vehicle has two separate fuel systems, one for gasoline or diesel and another for LPG, CNG or H_2. Because LPG, CNG and H_2 are stored in pressurized tanks, they cannot be simply pumped into the gasoline tank. Like flex-fuel vehicles, bi-fuel vehicle emissions vary from car to car depending on engine controls and the fuel chosen – making them not necessarily cleaner than a dedicated gas vehicle.

Hydrogen Fuel Cell Vehicle (FCVs): All H_2 FCVs are zero emission. Currently, most H_2 is harvested from natural gas – the cleanest and most efficient method at this time. The source of H_2 is an integral part of the emissions considerations, but H_2 FCVs themselves are zero emission. Not all FCVs are zero emission, for example, if they use methanol such as in a direct methanol FCV, they produce some carbon monoxide emissions and potential other trace constituents.

Diesel: Vehicles run on diesel achieve better fuel economy and contribute less to greenhouse gas emissions. And although emissions from diesel vehicles are better controlled because of improved engines, new emission control devices and reduced sulfur content in the fuel, diesel vehicles still have significant particulate and oxides of nitrogen emissions. Diesels have met only federal Tier I standards to date, which are about 4.5 times dirtier than California's least stringent LEV standard.

Common Terms

AER	All Electric Range	**GHG**	Greenhouse Gas	**NOx**	Oxides of Nitrogen
AFV	Alternative Fuel Vehicles	**H_2**	Hydrogen	**OBD**	On Board Diagnostics
AT PZEV	Advanced Technology Partial Zero Emission Vehicle	**HC**	Hydrocarbon	**PbA**	Lead Acid (battery)
BEV or EV	Battery Electric Vehicle	**HEV**	Hybrid Electric Vehicle	**PC**	Passenger Car
CaFCP	California Fuel Cell Partnership	**HEV 20**	Hybrid EV with 20 Miles All Electric Range	**PEM**	Proton Exchange Membrane (fuel cell)
CBG	Cleaner Burning Gasoline	**LDT**	Light Duty Truck	**PPM**	Parts Per Million
CEV	City Electric Vehicle	**LEV**	Low Emission Vehicle	**PZEV**	Partial Zero Emission Vehicle
CNG	Compressed Natural Gas	**LEV II**	1998 amendments to LEV program	**SULEV**	Super Ultra Low Emission Vehicle
CO_2	Carbon Dioxide	**LPG**	Liquid Petroleum Gas (Propane)	**ULEV**	Ultra Low Emission Vehicle
E85	85% Ethanol (gas blend)	**MDV**	Medium Duty Vehicle	**UDDS**	Urban Dynamometer Driving Schedule
FCEV or FCV	Fuel Cell Electric Vehicle	**MeOH**	Methanol	**VMT**	Vehicle Miles Traveled
FE	Fuel Efficiency	**NEV**	Neighborhood Electric Vehicle	**ZEM**	Zero Emission Motorcycle
FFEV	Full Function Electric Vehicle	**NiMH**	Nickel Metal Hydride (battery)	**ZEB**	Zero Emission Bus
g/mile	Grams per Mile	**NMOG**	Non Methane Organic Gas	**ZEV**	Zero Emission Vehicle

Fact Sheet

California Environmental Protection Agency
Air Resources Board

Cleanest Gasoline Powered Vehicles

Many new gasoline vehicles are being designed to produce extremely lower levels of emissions, and are achieving a Partial Zero Emission Vehicle, or PZEV rating by the California Air Resources Board (ARB). PZEVs are so clean because they meet ARB's most stringent tailpipe emission standard - Super Ultra Low Emission Vehicle, and have a 15 year/150,000 mile warranty and zero evaporative emissions.

Environmental Benefits

Gasoline vehicles with a PZEV rating are mass-produced in a variety of makes and models and are available to the public today. They have an immediate impact on air quality because they are popular models at affordable prices. In addition, the extended warranty provides added security that the vehicle will be maintained for a longer period of time.

Perks and Conveniences

Nothing new here - just a much cleaner version of the conventional internal combustion engine vehicle. In many instances car buyers may pay only $100 more for a cleaner vehicle model that comes with a better warranty. It is even possible to be driving a clean car and not even know it!

Technology

Automakers are continually making advancements in technologies that improve their vehicles. Tremendous benefits have resulted alone by industry's ability to simplify, refine, and reduce the costs of their emission control systems. PZEVs are primarily four cylinder engines, however there are some five and six cylinder models available. Many PZEVs utilize various combinations of multiple catalysts, several oxygen sensors, exhaust gas recirculation, and an air pump.

Facts

- In 2003 there were 15 PZEV models available. There are 27 models in 2004.
- BMW, Ford, Volvo, Toyota, Honda, Subaru, Hyundai, Mitsubishi, Nissan and Volkswagen all have several PZEV models available to consumers.
- Cars with a PZEV emission rating have such tight pollution controls, and the burning of fuel is so complete, that in very smoggy urban areas, exhaust out of the tailpipe can actually be cleaner than the air outside.

- Ford's 2003 Focus certified with a PZEV emissions rating, has a larger engine that weighs less, produces more horsepower, and is more fuel-efficient than the dirtier version of that same vehicle.
- The California Air Resources Board estimates 140,000 PZEVs will be on CA roads in 2004 - reaching 700,000 more each year by 2011 in CA alone.
- Gasoline vehicles meeting PZEV emissions standards sometimes have even lower emissions than hybrid or alternate fuel vehicles.

Where can I get more information?

Please contact the ARB toll-free at (800) END-SMOG/(800) 363-7664 (California only) or (800) 272-4572. You may obtain this document in an alternative format by contacting ARB's Americans with Disabilities Act Coordinator at (916) 322-4505 (voice); (916) 324-9531 (TDD, Sacramento only); or (800) 700-8326 (TDD, outside Sacramento).

Alternate Fuel Vehicles

An Alternate Fuel Vehicle (AFV) is a vehicle that can operate on a fuel other than gasoline or petroleum based diesel, such as biologically produced diesel (biodiesel) electricity, ethanol, hydrogen, methanol, natural gas, or propane. Alt Fuel vehicles range in function and size from small passenger cars to large 18-wheeler trucks or transit buses. Off-road products such as forklifts, and agricultural and construction equipment are also available with alt fuel systems.

Environmental Benefits

AFV's produce fewer emissions than those powered by gasoline or diesel fuel. Emission reductions of up to 80 percent for pollutants such as carbon monoxide, carbon dioxide, non-methane organic gas, oxides of nitrogen, or particulate matter can be achieved. The amount of emission reductions varies by alt fuel type and pollutant.

Perks and Conveniences

Using alternative fuels helps reduce the nation's dependence on imported oil. Alt Fuels can be derived from renewable biological feedstock or are a by-product of petroleum production. For example ethanol can be fermented from corn or wood waste, while natural gas or propane is produced in conjunction with crude oil production. Some alt fuels can also reduce vehicle maintenance requirements. For example, spark plugs from a propane-fueled vehicle last from 80,000 to 100,000 miles and engines can last 2 to 3 times longer than gasoline- or diesel-fueled engines.

Refueling

Depending on the fuel, a vehicle may be configured with either dedicated or bi-fuel systems. Vehicles with dedicated systems are designed to run exclusively on a particular alt fuel while bi-fuel vehicles have two separate fueling systems that can operate on either the alternative or conventional fuel. Different alt fuels are dominant in different regions of the country. Propane is the most widely available, with stations in every state, while ethanol blends are concentrated in the Midwest and plains states. Generally refueling times are comparable with those needed for gasoline or diesel refueling.

Technology

Alt fuel vehicle availability varies by fuel type. Currently light duty vehicles capable of using compressed natural gas (CNG), ethanol, and blended biodiesel are in production. Various heavy-duty vehicles using CNG, liquefied natural gas, propane, or biodiesel are available. Alt fuel conversion kits are available for Propane. The majority of propane-fueled vehicles are the result of aftermarket conversion.

Fact Sheet

California Environmental Protection Agency
Air Resources Board

Safety

Alt fuel vehicles meet federal motor vehicle safety requirements. The pressurized containers of fuels such as liquefied propane and compressed natural gas go through rigorous safety testing.

Web sites with additional information:

- Alternative Fuel Data Center: www.afdc.doe.gov
- Clean Cities: www.ccities.doe.gov
- Office of the National BioDiesel Board: www.biodiesel.org
- Renewable Fuels Associations: www.ethanolrfa.org
- American Hydrogen Association: www.clean-air.org
- Methanol Institute: www.methanol.org
- Natural Gas Vehicle Coalition: www.ngvc.org/ngv/ngvc.nsf
- Propane Education and Research Council: www.propanecouncil.org

Where can I get more information?

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Hybrid Electric Vehicles

Hybrid electric vehicles (HEVs) commercially available today combine an internal combustion engine with a battery and electric motor. This combination offers the extended range and rapid refueling of a conventional vehicle, while reducing energy requirements and emissions of today's vehicles. The practical benefits of HEVs include improved fuel economy and lower emissions compared to conventional vehicles. The inherent flexibility of HEVs allows them to be used in a wide range of applications, from personal transportation to commercial hauling.

Environmental Benefits

More efficient cars can make a big difference to society in terms of environmental benefits, and the serious deterioration of urban air has motivated regulators to require cleaner cars. Production HEVs will reduce smog-forming pollutants over the current national average. Hybrids will never be true zero-emission vehicles, however, because of their internal combustion engine. But hybrids certified to the ARB's super ultra low emission standard can significantly reduce ozone precursor emissions and global-warming pollutants by a third to a half, and future models may cut emissions by even more.

Perks and Conveniences

Auto manufacturers have begun to produce HEVs with comparable performance, safety, and cost to conventional vehicles. By combining gasoline with electric power, hybrids have the same or greater range than traditional combustion engines, thus reducing the number of trips to the gasoline station. Improved fuel economy reduces greenhouse gas emissions and provides savings to help offset the incremental capital cost of the vehicle.

Refueling

Today's hybrid electric vehicles refuel at the gas station. These vehicles use both gasoline and electricity that is generated on-board the vehicle. As a result, refueling is the same as conventional vehicles, although generally required less often due to improved fuel economy. Future HEVs may refuel at both the gas station and plug in, and thus offer more electric drive miles, improve efficiency, and reduce operating costs.

Technology

Many configurations are possible for HEVs. Essentially, a hybrid combines an energy storage system, a power unit such as a spark ignition engine, and a vehicle propulsion system. The primary options for energy storage include batteries, ultracapacitors, and flywheels. Although batteries are by far the most common energy storage choice, research is still being done in other energy storage areas. Propulsion can come entirely from an electric motor, such as in a series configuration, or the engine might provide direct mechanical input to the vehicle propulsion system in a parallel configuration system. A hybrid's efficiency and emissions depend on the particular combination of subsystems, how these subsystems are integrated into a complete system, and the control strategy that integrates the subsystems. A hydrogen fuel cell hybrid, for example, would produce only water as a by-product and run at greater overall efficiency than a battery-electric vehicle that uses wall-plug electricity.

Facts

- HEVs are substantially more efficient than conventional vehicles.
- Regenerative braking helps minimize energy loss and recover the energy used to slow down or stop a vehicle.
- Engines can be sized to accommodate average load, not peak load, which reduces the engine's weight.
- Fuel efficiency is greatly increased (hybrids consume significantly less fuel than vehicles powered by gasoline alone).
- Emissions are decreased.
- HEVs can reduce dependency on fossil fuels because they can run on alternative fuels.

Safety

Hybrid-electric vehicles meet all federal motor vehicle safety requirements. The batteries in HEVs are sealed and all high-voltage circuits are protected from casual contact. High-voltage circuits are marked, color-coded and posted with warnings to advise of their presence. These vehicles pose no additional risks over a conventional vehicle.

Where can I get more information?

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Battery Electric Vehicles

General Information

Electric vehicles (EVs) are cars that run on electricity stored in batteries. EVs are often confused with hybrid electric vehicles which combine an internal combustion engine with a battery. EVs are the only truly zero emission car available today because they have no tailpipe exhaust and no evaporative emissions from fuel systems. Manufacturers have developed a broad spectrum of EVs - from neighborhood electric cars which can be used for short trips around town to full function electric cars which can be used for longer trips and have the body of conventional cars. The availability and styles of these vehicles vary from year to year, but with battery technology getting more sophisticated, manufacturers will have the ability to design electric vehicles with extended range, faster charging and more power.

Perks and Conveniences

- Drive alone in the HOV lane
- Free parking in some areas
- Cash incentives towards the lease or purchase of an EV from ARB and some local agencies
- Tax incentives from the Federal government
- You can recharge at your home or work --you don't have to make a trip to the gas station
- Fuel costs are less than a conventional car estimated at $1 to $2 a day for a 30 to 70 mile commute
- Maintenance costs are lower because there are fewer moving parts to service and repair
- No noisy engine

Refueling

EVs are fueled by electricity and can be recharged at a charger installed at your home or workplace, or can be found at many other locations such as Costco and your local shopping mall. Currently there are two types of chargers, however in 2006 all vehicles produced will use the same system. Charging time varies depending on how "empty" the battery is, how much energy the battery holds (or how big the tank is) and other factors. In general, it takes approximately two to five hours to recharge vehicles that are ¼ to ¾ full and approximately six to eight hours to recharge vehicles that are on "empty." However, you'll probably be working, sleeping, shopping or watching a movie so it really doesn't seem that long.

Technology

The heart of an EV has three main components: the batteries, the electric motor controller, and the electric motor. The controller takes power from the batteries and delivers it to the motor. The batteries of an EV can vary in type, number, voltage and placement. The different battery types available now are Nickel-Cadmium, Nickel metal hydride, Lithium Ion, and Lead acid. To recharge the batteries, there is a charger component on the car which takes the electricity from a power source (ultimately the power plant) and converts the current from alternating current (AC) to direct current (DC).

Facts

- No tailpipe exhaust or evaporative emissions
- No emissions system which can degrade or fail with time
- No emissions from the refining of fuel and service stations Electric vehicles are the cleanest and most environmentally friendly car around
- EVs reduce pollutants by more than 90 percent when compared to the cleanest conventional gasoline-powered vehicles (even when factoring in the emissions from power plants generating the electricity to the charge the vehicle).
- Fuel costs for a gasoline vehicle can be over five times greater than an electric vehicle.
- By driving an electric vehicle with a 30-mile commute, a person can reduce gasoline consumption by an estimated 750 gallons annually.

Safety

EVs meet all federal motor vehicle safety requirements. The batteries are sealed and all high-voltage circuits are protected from casual contact. High-voltage circuits are marked, color-coded and posted with warnings to advise of their presence. These vehicles pose no additional risks over a conventional vehicle.

Where can I get more information?

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Battery Electric Vehicles

Refueling, Energy Use and Charging

The success of the Air Resources Board's zero emission vehicle (ZEV) program can be seen today through the growing availability of hybrid electric vehicles and near-zero emission gasoline combustion vehicles. Although the battery electric vehicle (EV) market has changed recently due to a shift to fuel cell technology, there have been over 4,000 EVs on California's roads and many remain on the roads today.

In addition, the market for city and neighborhood EVs continues to be strong. These smaller EVs are inexpensive, have zero tailpipe emissions, and provide excellent around town transportation. Information and incentives on these and other clean vehicles may be found at www.DriveClean.ca.gov. This document provides general information about EVs, including refueling, energy use, and public and private charging.

Refueling EVs

Electric vehicles are "fueled" by a battery charger that transfers electricity provided by electric utilities into the vehicle battery to "recharge" it. The primary electric vehicle charging station is located at the residence, business, or fleet facility where the vehicle is garaged. There are also a number of public charging sites that are available.

Charging Equipment: Conductive and inductive (small paddle and large paddle) charging systems are most common; however, some city or neighborhood EVs may be plugged right into a 110-v outlet. Charging equipment is usually sold to consumers by distributors, but in some cases can be purchased directly from the manufacturer.

Charging Time: The amount of time that it takes to charge varies, and depends on how "empty" the battery is, how much energy the battery holds, and other factors. In general, it takes from two to five hours to charge most EVs that are ¼ full to ¾ full, and from four to eight hours to fully charge an electric vehicle from empty to full. Most people find charging at night to be extremely convenient and the primary way that they charge their vehicle.

Fueling Costs: EVs are often charged at home using a separate electricity meter. Electric utilities have offered special rates to EV customers who take advantage of "time-of-use" metering so that they only charge their car at night. This helps the utilities by shifting the demand for electricity needed for EVs to the period when overall demand is at its lowest. The rates offered using these time-of-use meters has been as low as $0.05 per kilowatt-hour. So, charging an EV would cost approximately a dollar a day.

EVs and Energy Use

If 10,000 EVs in California all plugged in at the same time to recharge, they would represent less than 0.06 percent of California's total power demand. Consumer surveys and utility observations note that as many as 95 percent of the State's current EV drivers charge at night while at home, taking advantage of the excess capacity. This excess capacity is as much as 50 percent of the total system's capacity.

EVs use on average a little less than half a kilowatt-hour per mile as they drive. Since Californian's drive an average of about 36 miles per day, a typical estimate of electricity used daily by an EV is about 15 kilowatt-hours.

Public Charging Stations

There are more than 1000 charging stations installed throughout California. It is very easy to use these stations because they are available at a variety of locations, including shopping centers, city parking lots, airports, hotels, government offices, and other businesses. Charging is currently provided at no cost to the driver; however, entrance or parking fees may be applicable. Helpful web sites to find public charging stations in your area, are:

Type of Directory	Internet Address
California Directory maintained by CALSTART	www.cleancarmaps.com
National Directory maintained by U.S Dept of Energy	www.afdc.nrel.gov/altfuel/electric.html
List of chargers maintained by electric vehicle drivers	www.evchargernews.com
San Diego area information provided by San Diego Gas and Electric	www.sdge.com/EV/Maps/index.html
Los Angeles area information, provided by LADWP	www.ladwp.com/ladwp/cms/ ladwp000791.jsp

Reporting Charging Equipment Problems

Charging equipment problems may be reported to the following agencies:

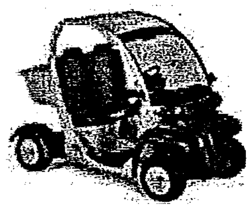
Type of Equipment	Phone	Business/Organization
Inductive (all models)	888-890-4638	SMUD/Clean Fuel Connection
Conductive (models ICS-200, MCS-100, DS-50)	888-823-8077	EVI/Electric Vehicle Infrastructure
Conductive (equipment manufactured by Avcon)	800-433-7642	Avcon
Public Chargers		www.cleancarmaps.com

Additional Information

Please contact the ARB toll-free at (800) END-SMOG/(800) 363-7664 (California only) or (800) 242-4450. More information on the Zero Emission Vehicle Program is available on ARB's web site at www.arb.ca.gov/msprog/zevprog/zevprog.htm or at www.DriveClean.ca.gov.

You may obtain this document in an alternative format by contacting ARB's ADA Coordinator at (916) 322-4505 (voice); (916) 324-9531 (TDD, Sacramento area only); or (800) 700-8326 (TDD, outside Sacramento).

The energy crisis facing California is real. Every Californian needs to take immediate action to reduce energy consumption. For a list of sample ways you can reduce demand and cut your energy costs, see our web site: http://www.arb.ca.gov



FEATURED VEHICLE

Global Electric Motors E825 2 Passenger

MORE INFO

VEHICLE SEARCH

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LINKS
CALIFORNIA AIR RESOURCES BOARD SITE
CLIMATE CHANGE
SITE DEFINITIONS

DID YOU KNOW?

Carpool – leaving your car at home just two days a week will reduce your carbon dioxide emissions by 1,590 pounds per year.

VEHICLE TYPES

ELECTRIC | HYBRID ELECTRIC | ALTERNATIVE FUEL | FUEL CELL | CLEANER GAS CARS

VIEW CARS

ELECTRIC

INTRODUCTION | ENVIRONMENTAL BENEFITS | PERKS AND CONVENIENCES
CHARGING/FUELING | TECHNOLOGY | FACTS | SAFETY

Introduction

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Environmental Benefits

EVs are superior for clean air over all other cars because they have:

- no tail pipe exhaust
- no evaporative emissions
- no emissions system which can degrade or fail with time
- no emissions from the refining of fuel and service stations

With widespread use EVs can

- reduce emissions of carbon dioxide, a green house gas that contributes to global warming
- lessen our cancer risk from exposure to toxic air contaminants such as benzene
- reduce oil consumption and dependence on imported oil

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Perks and Conveniences

There are many perks and conveniences in driving a battery electric car. Almost too many to list!

- Drive alone in the HOV lane—bypass all that traffic
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Charging/Fueling

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Safety

EVs meet all federal motor vehicle safety requirements. The batteries are sealed and all high-voltage circuits are protected from casual contact. High-voltage circuits are marked, color-coded and posted with warnings to advise of their presence. These vehicles pose no additional risks over a conventional vehicle.

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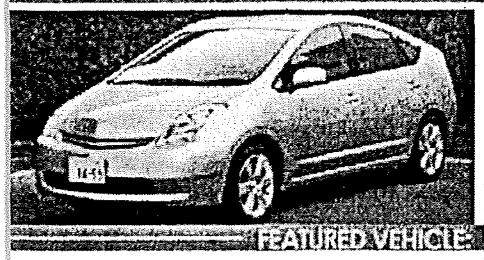
DRIVECLEAN.CA.GOV A ZERO & NEAR - ZERO EMISSION VEHICLE GUIDE BROUGHT TO YOU BY THE CALIFORNIA AIR RESOURCES BOARD

SEARCH

HOME DRIVE CLEAN CHARGING/FUELING INCENTIVES NEWS & EVENTS RESOURCES



Toyota Prius

MORE INFO

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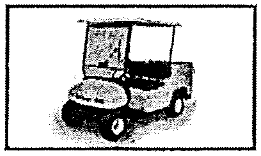
DID YOU KNOW?

Cars with ARB's very clean PZEV emission rating are familiar vehicles with affordable prices - such as a $13,000 Ford Focus compact and a $28,000 BMW 325i sedan.

CLEAN VEHICLE SEARCH

SEARCH RESULT:

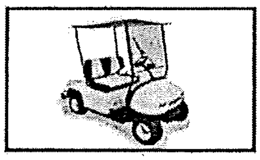


2003 Columbia ParCar ZEV Cargo Express, 2 Passenger

Integrating performance, style and practicality in zero emission transportation.

Emission Rating:
ZEV

MORE INFO

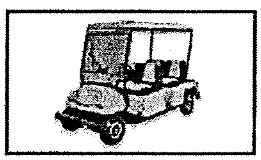


2003 Columbia ParCar ZEV Commuter, 2 Passenger

Integrating performance, style and practicality in zero emission transportation.

Emission Rating:
ZEV

MORE INFO

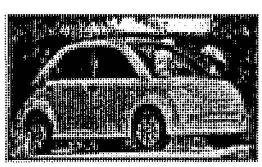


2003 Columbia ParCar ZEV Commuter, 4 Passenger

Integrating performance, style and practicality in zero emission transportation.

Emission Rating:
ZEV

MORE INFO

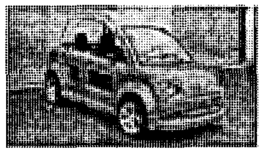


2003 Dynasty Electric Car Corp. IT Sedan

"IT" is Innovative Transportation, a smart choice for short commutes around neighborhoods, communities, campuses, resorts or business complexes. The fully enclosed Sedan with its automotive styling provides a viable alternative to your driving needs and you simply plug it in at home to recharge the batteries.

Emission Rating:
ZEV

MORE INFO

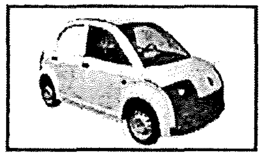


Emission Rating:
ZEV

2003 Dynasty Electric Car Corp. IT Sport

The Sport raised roof design lets you throw in the cooler and you're off to the park or beach. There's room for four, plenty of space for tennis racquets, surfboards, volleyball equipment, picnic baskets....whatever fits your idea of fun. The Sport meets or exceeds all Federal requirements.

MORE INFO

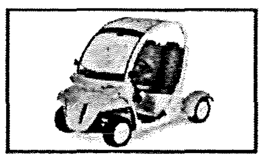


Emission Rating:
ZEV

2003 Dynasty Electric Car Corp. IT Van

Ideal for light industrial and commercial operations where a quiet pollution free service vehicle is required, the "IT" Van with its 4 doors and rear hatchback provides an easily accessible enclosed vehicle for transporting goods such as electronic equipment, maintenance equipment or gardening supplies, anything that you want to keep out of the weather.

MORE INFO

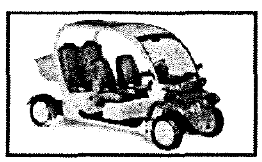


Emission Rating:
ZEV

2003 Global Electric Motors E825 2 Passenger

The GEM E825 is a street legal neighborhood EV for all roads posted up to 35 miles per hour. It meets all federal safety standards for low speed vehicles, is zero emission and costs only pennies per mile to operate.

MORE INFO

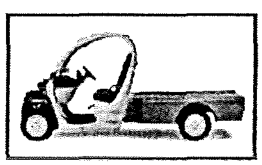


Emission Rating:
ZEV

2003 Global Electric Motors E825 4 Passenger

For families on the go, the four passenger GEM is your alternative travel solution. The GEM offers and eye catching design and a fun new way to get around town for just pennies per mile.

MORE INFO

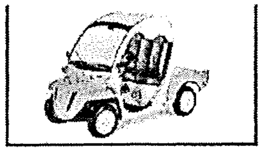


Emission Rating:
ZEV

2003 Global Electric Motors E825 Long-back

The GEM long-back NEV is the answer for those who desire environmentally sound around-town transportation and also need additional utility. This GEM transports two people while offering the ability to haul a six-foot ladder and your tools.

MORE INFO

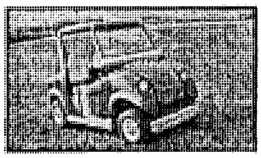


2003 Global Electric Motors E825 Short-back

The GEM 2 passenger short back NEV serves as a mini-hauler that's perfect for carrying everything from groceries to a new bunch of small plants. A variety of accessories are available to custom tailor this GEM to your work needs.

Emission Rating:
ZEV

MORE INFO

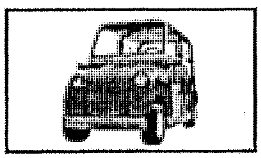


2003 Lafayette County Car Company LC3 II Series

The LC3 II is a two seat vehicle, perfect for the couple that is on the move, but doesn't want the additional expense of a second full-size car.

Emission Rating:
ZEV

MORE INFO

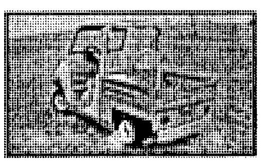


2003 Lafayette County Car Company LC3 IV Series

The LC3 IV is a four-seat vehicle, fully equipped for a mobile lifestyle requiring reliability, comfort, versatility and safety.

Emission Rating:
ZEV

MORE INFO

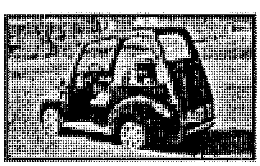


2003 Lafayette County Car Company LC3 Utility

The LC3 utility vehicle has a 4' x 4' bed and a total carrying capacity of 860 pounds. It is equally efficient for use at home or work, on turf or street. This vehicle meets all federal regulations for low speed vehicles.

Emission Rating:
ZEV

MORE INFO

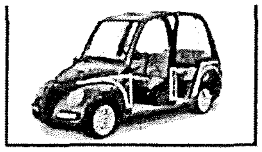


2003 Lido Motors Lido Coupe

The Lido is a a street-legal, low speed personal vehicle designed for short commutes. It can travel up to 25 mph on city streets with a posted speed limit of 35 mph.

Emission Rating:
ZEV

MORE INFO

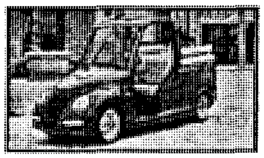


2003 Lido Motors Lido Sedan

The Lido is a a street-legal, low speed personal vehicle designed for short commutes. It can travel up to 25 mph on city streets with a posted speed limit of 35 mph.

Emission Rating:
ZEV

MORE INFO

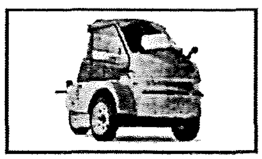


2003 Lido Motors Lido Wagon Runabout

The Lido is a a street-legal, low speed personal vehicle designed for short commutes. It can travel up to 25 mph on city streets with a posted speed limit of 35 mph.

Emission Rating:
ZEV

MORE INFO

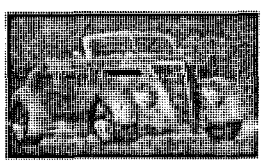


2003 Nevco Gizmo

A revolutionary concept in personal transportation. Never before has an enclosed, electric vehicle for around town been so affordable, so unique in design, and so much fun. This vehicle is capable of being used for everyday trips, and it quickly accelerates up to 40 mph on an amazingly low one penny per mile of electricity.

Emission Rating:
ZEV

MORE INFO

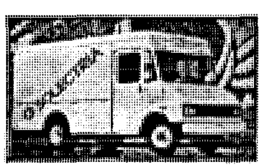


2003 Phoenix Motorcars, Inc. Phoenix 1

Phoenix Motorcars delivers zero-emission, freeway speed limited edition automobiles with classic vintage styling. All models feature onboard computer diagnostics , four-wheel independent suspension, four-wheel disc brakes and high efficiency regenerative braking. Go green in style.
*Carpool eligible

Emission Rating:
ZEV

MORE INFO

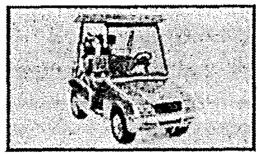


2003 Solectria Citivan

The Solectria CitiVan electric delivery van is ideal for demanding applications in urban environments. A reliable Solectria electric drive system eliminates the need for tune-ups, oil changes, exhaust and brake service, and virtually all other routine service items. Rugged construction assures long vehicle life and low maintenance costs.
*Carpool eligible

Emission Rating:
ZEV

MORE INFO

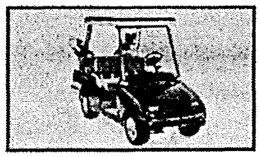


2003 Western Golf Car Elegante

The Elegante is a low speed vehicle suitable for around-the-town traveling on roadways with a posted speed limit of 25 mph or less. The back seat allows four to ride in comfort, and a convertable model is available.

Emission Rating:
ZEV

MORE INFO

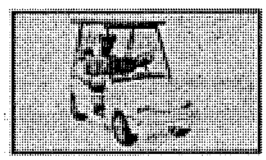


2003 Western Golf Car Model 100

The Model 100 is a low speed vehicle suitable for around-the-town traveling on roadways with posted speed limits of 25 mph or less. The newly designed dash has an am/fm stereo and locking glove box, and the front trunk strorage area makes packing easy and convenient.

Emission Rating:
ZEV

MORE INFO

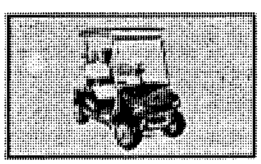


2003 Western Golf Car Model 300

The Model 300 is a low speed vehicle suitable for around-the-town traveling on roadways with speed limits of 25 mph or less. The convenient front trunk storage, built in cooler, and newly designed dash with radio and locking glove box make this NEV a clean and comfortable way to ride.

Emission Rating:
ZEV

MORE INFO



2003 Western Golf Car Model 400

The Model 400 is a low speed vehicle suitable for around-the-town traveling on roadways with speed limits of 25 mph or less. The convenient front trunk storage, built in cooler, and newly designed dash with radio and locking glove box make this NEV a clean and comfortable way to ride.

Emission Rating:
ZEV

MORE INFO

BACK TO VEHICLE SEARCH

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SEARC

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Ford F150 CNG

VEHICLE TYPES

ELECTRIC | HYBRID ELECTRIC | ALTERNATIVE FUEL | FUEL CELL | CLEANER GAS CAR!

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DID YOU KNOW?

Cars with ARB's PZEV emission rating achieve incredibly low tailpipe emissions and have zero evaporative emissions from the fuel system.

HYBRID ELECTRIC

INTRODUCTION | ENVIRONMENTAL BENEFITS | PERKS AND CONVENIENCES
CHARGING/FUELING | TECHNOLOGY | FACTS | SAFETY

Introduction

Hybrid electric vehicles (HEVs) commercially available today combine an internal combustion engine with a battery and electric motor. This combination offers the extended range and rapid refueling of a conventional vehicle, while reducing energy requirements and emissions of today's vehicles. The practical benefits of HEVs include lower emissions and improved fuel economy compared to conventional vehicles. The inherent flexibility of HEVs allows them to be used in a wide range of applications, from personal transportation to commercial hauling.

Environmental Benefits

Hybrid electric cars can make a big difference to society in terms of environmental benefits, and the serious deterioration of urban air has motivated regulators to require cleaner cars. Production HEVs will reduce smog-forming pollutants over the current national average. Hybrids will never be true zero-emission vehicles, however, because of their internal combustion engine. But hybrids certified to the ARB's super ultra low emission standard can significantly reduce ozone precursor emissions and global-warming pollutants by a third to a half, and future models may cut emissions by even more.

BACK TO TOP

Perks and Conveniences

Auto manufacturers have begun to produce HEVs with comparable performance, safety, and cost to conventional vehicles. By combining gasoline with electric power, hybrids have the same or greater range than traditional combustion engines, thus reducing the number of trips to the gasoline station. Improved fuel economy provides savings to help offset the incremental capital cost of the vehicle.

BACK TO TOP

Charging/Fueling

Today's hybrid electric vehicles refuel at the gas station. These vehicles use both gasoline and electricity that is generated on-board the vehicle. As a result, refueling is the same as conventional vehicles, although generally required less often due to improved fuel economy. Future HEVs may refuel at both the gas station and plug in, and thus offer more electric drive miles, improve efficiency, and reduce operating costs.

BACK TO TOP

Technology

Many configurations are possible for HEVs. Essentially, a hybrid combines an energy storage system, a power unit such as a spark ignition engine, and a vehicle propulsion system. The primary options for energy storage include batteries, ultracapacitors, and flywheels. Although batteries are by far the most common energy storage choice, research is still being done in other energy storage areas. Propulsion can come entirely from an electric motor, such as in a series configuration, or the engine might provide direct mechanical input to the vehicle propulsion system in a parallel configuration system. A hybrid's efficiency and emissions depend on the particular combination of subsystems, how these subsystems are integrated into a complete system, and the control strategy that integrates the subsystems. A hydrogen fuel cell hybrid, for example, would produce only water as a by-product and run at greater overall efficiency than a battery-electric vehicle that uses wall-plug electricity.

BACK TO TOP

Facts

- Emissions are decreased.
- HEVs are substantially more efficient than conventional vehicles.
- HEVs can reduce dependency on fossil fuels because they can run on alternative fuels.
- Regenerative braking helps minimize energy loss and recover the energy used to slow down or stop a vehicle.
- Engines can be sized to accommodate average load, not peak load, which reduces the engine's weight.
- Fuel efficiency is greatly increased (hybrids consume significantly less fuel than vehicles powered by gasoline alone).

Safety

Hybrid-electric vehicles meet all federal motor vehicle safety requirements. The batteries in HEVs are sealed and all high-voltage circuits are protected from casual contact. High-voltage circuits are marked, color-coded and posted with warnings to advise of their presence. These vehicles pose no additional risks over a conventional vehicle.

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SEARCH

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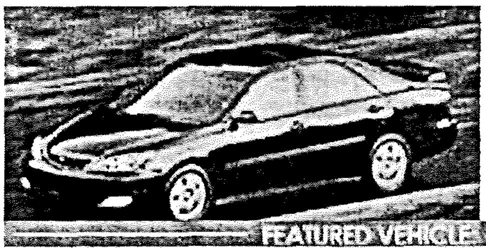
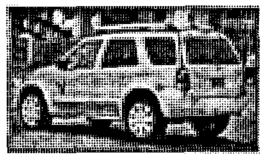


Toyota Camry LE, SE or XLE

MORE INFO

CLEAN VEHICLE SEARCH

SEARCH RESULT:

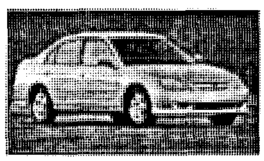


2005 Ford Escape Hybrid

The Escape Hybrid offers improved fuel economy and fewer pollutants than a conventional SUV, without the hassle of daily recharging an electric vehicle--ideal for environmentally aware drivers. With the Escape Hybrid, you don't sacrifice interior space to gain an environmentally-responsible, lower emissions vehicle that also features a fully-independent rear suspension, 4WD capability and V6-like acceleration. Available to consumers late summer 2004.

Emission Rating:
Not yet rated

MORE INFO

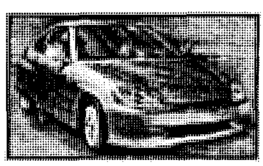


2004 Honda Civic Hybrid

The Hybrid is a Civic inside and out, so you can expect a safe, fun and dependable ride. Plus, its powertrain uses gasoline-electric technology that lets you travel up to 650 miles on a single tank of gas. And its battery recharges itself, because you've got better things to do than plug in and wait.

Emission Rating:
AT PZEV

MORE INFO



2004 Honda Insight Hybrid

The Honda Insight is a very affordable environmentally conscious vehicle utilizing extraordinary technology to achieve the best gas mileage. It is sleek and sporty with a lively VTEC engine and an electric motor.

Emission Rating:
SULEV

MORE INFO

2004 Toyota Prius

The all new Toyota Prius hybrid beams with a wealth of performance features, interior amenities and cargo space that places this hybrid vehicle on the forefront of automotive technology and value.

Emission Rating:
AT PZEV

VEHICLE SEARCH

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DID YOU KNOW?

To travel one mile, an electric vehicle consumes the same electricity as a 100-watt light bulb turned on for 4 hours.

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FEATURED VEHICLE

Subaru Legacy Outback Wagon

MORE INFO

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DID YOU KNOW?

Every vehicle found on DriveClean.ca.gov emits only 2 pounds or less of hydrocarbons when driven 100,000 miles. In comparison, a new 1965 car emitted about 2,000 pounds of hydrocarbons in 100,000 miles.

VEHICLE TYPES

ELECTRIC | HYBRID ELECTRIC | ALTERNATIVE FUEL | FUEL CELL | CLEANER GAS CARS

VIEW CARS

ALTERNATIVE FUEL

INTRODUCTION | ENVIRONMENTAL BENEFITS | PERKS AND CONVENIENCES
CHARGING/FUELING | TECHNOLOGY | SAFETY | LINKS

Introduction

An Alternative Fuel Vehicle (AFV) is a vehicle that can operate on a fuel other than gasoline or petroleum based diesel, such as biologically produced diesel (biodiesel) electricity, ethanol, hydrogen, methanol, natural gas, or propane. Alt Fuel vehicles range in function and size from small passenger cars to large 18-wheeler trucks or transit buses. Off-road products such as forklifts, and agricultural and construction equipment are also available with alt fuel systems.

Environmental Benefits

AFVs produce fewer emissions than those powered by gasoline or diesel fuel. Emission reductions of up to 80 percent for pollutants such as carbon monoxide, carbon dioxide, non-methane organic gas, oxides of nitrogen, or particulate matter can be achieved. The amount of emission reductions varies by alt fuel type and pollutant.

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Perks and Conveniences

Using alternative fuels helps reduce the nation's dependence on imported oil. Alt Fuels can be derived from renewable biological feedstock or are a by-product of petroleum production. For example ethanol can be fermented from corn or wood waste, while natural gas or propane is produced in conjunction with crude oil production. Some alt fuels can also reduce vehicle maintenance requirements. For example, spark plugs from a propane-fueled vehicle last from 80,000 to 100,000 miles and engines can last 2 to 3 times longer than gasoline- or diesel-fueled engines.

BACK TO TOP

Charging/Fueling

Depending on the fuel, a vehicle may be configured with either dedicated or bi-fuel systems. Vehicles with dedicated systems are designed to run exclusively on a particular alt fuel while bi-fuel vehicles have two separate fueling systems that can operate on either the alternative or conventional fuel. Different alt fuels are dominant in different regions of the country. Propane is the most widely available, with stations in every state, while ethanol blends are concentrated in the Midwest and plains states. Generally refueling times are comparable with those needed for gasoline or diesel refueling.

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Technology

Alt fuel vehicle availability varies by fuel type. Currently light duty vehicles capable of using compressed natural gas (CNG), ethanol, and blended biodiesel are in production. Various heavy-duty vehicles using CNG, liquefied natural gas, propane, or biodiesel are available. Alt fuel conversion kits are available for Propane. The majority of propane-fueled vehicles are the result of aftermarket conversion.

≜ BACK TO TOP

Safety

Alt fuel vehicles meet federal motor vehicle safety requirements. The pressurized containers of fuels such as liquefied propane and compressed natural gas go through rigorous safety testing.

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Links

The following web sites provide additional information:

Alternative Fuel Data Center
Clean Cities
Office of the National BioDiesel Board
Renewable Fuels Associations
American Hydrogen Association
Methanol Institute
Natural Gas Vehicle Coalition
Propane Education and Research Council

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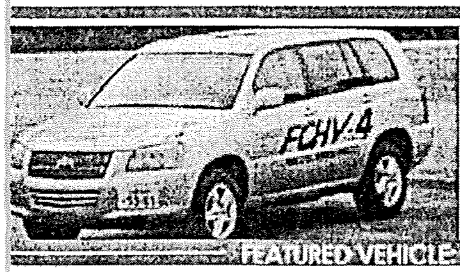

FEATURED VEHICLE

oyota Fuel Cell Hybrid Vehicle(FCHV)

MORE INFO

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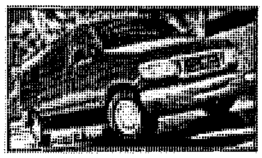
ID YOU KNOW?

ars with ARB's PZEV emission rating achieve ncredibly low tailpipe emissions and have ero evaporative emissions from the fuel ystem.

CLEAN VEHICLE SEARCH

SEARCH RESULT:

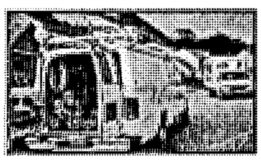


2004 Ford E250 CNG Van

North America's most trustworthy, versatile Van, designed to help sustain our environment.
*Carpool eligible

Emission Rating:
SULEV

MORE INFO

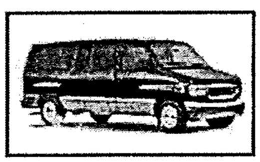


2004 Ford E350 CNG SuperDuty Ext. Van

One van for all you do; Its roomy, versatile design fits any need.
*Carpool eligible

Emission Rating:
SULEV

MORE INFO

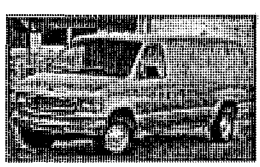


2004 Ford E350 CNG SuperDuty Ext. Wagon

North America's most trustworthy, versatile Wagon, designed to help sustain our environment.
*Carpool eligible

Emission Rating:
SULEV

MORE INFO

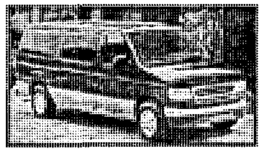


2004 Ford E350 CNG SuperDuty Van

Based on best selling van 24 years running with Best in Class quality.
*Carpool eligible

Emission Rating:
SULEV

MORE INFO

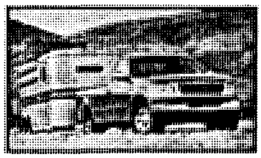


2004 Ford E350 CNG SuperDuty Wagon

The best-selling alternatively fueled wagon since 1997.
*Carpool eligible

Emission Rating:
SULEV

MORE INFO

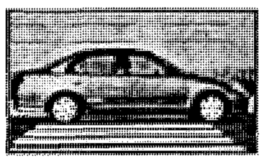


2004 Ford F150 CNG

The F-Series "Heritage" Dedicated NGV pickup is the "Cleanest Emissions Full-Size Pickup on the Planet." With SULEV emissions it is your fleet's cleanest choice to meet EPAct mandates. Also available to the general public in North American states in XL Regular Cab 4x2.
*Carpool eligible

Emission Rating:
SULEV

MORE INFO



2004 Honda Civic GX

A natural-gas vehicle designed to meet the needs of your fleet. That's why the Civic GX was named the cleanest internal-combustion vehicle on Earth by the EPA. And even though the GX is powered by natural gas, it's still got everything you expect from a Civic, like a roomy cabin and responsive acceleration. Fact is, the GX offers just about everything you could ask for in an AFV. Naturally.
*Carpool eligible

Emission Rating:
AT PZEV

MORE INFO

BACK TO VEHICLE SEARCH

ido Motors Lido Coupe

MORE INFO

VEHICLE SEARCH

DID YOU KNOW?

ars with ARB's very clean PZEV emission ating are familiar vehicles with affordable rices - such as a $13,000 Ford Focus ompact and a $28,000 BMW 325i sedan.

VEHICLE TYPES

ELECTRIC | HYBRID ELECTRIC | ALTERNATIVE FUEL | FUEL CELL | CLEANER GAS CARS

VIEW CARS

FUEL CELL

INTRODUCTION | ENVIRONMENTAL BENEFITS | PERKS AND CONVENIENCES
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Introduction

Fuel cells have the power to change our future. A breakthrough "clean machine," the fuel cell harnesses the chemical energy of hydrogen and oxygen to generate electricity without combustion or pollution. Fuel cells will power the car of tomorrow -- quieter, cleaner and more energy efficieint, with equivalent range and performance. The benefits will be extraordinary, in national energy security, cleaner air, and economic opportunity.

Environmental Benefits

When operating directly with hydrogen, there are no polluting emissions and no greenhouse gases from a fuel cell, only water and heat. If the hydrogen is generated by reforming fossil fuels, some greenhouse gases are released, but much less than the amount produced by conventional vehicles. In addition to these benefits, fuel cells could dramatically reduce urban air pollution, decrease oil imports, reduce the trade deficit and produce American jobs.

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Perks and Conveniences

Fuel cell engines offer a combination of the range of conventional combustion engines with low fuel consumption, minimal or no harmful emissions, low noise emissions, and the comfort of an electric vehicle.

Charging/Fueling

Today, fuel cell fueling stations don't exist, except for a few prototype facilities put into service for R&D purposes by the California Fuel Cell Partnership and others. In the future, when you drive your fuel cell vehicle, the gas station you currently use may be the place where you'll get hydrogen...or perhaps methanol...or a new grade of gasoline. All of these fuels and more are being considered and tested as fuels for fuel cell vehicles.

Developing the infrastructure for producing and distributing the fuel for fuel cell vehicles is a major task, and there are many questions and challenges to be addressed. Depending on how the hydrogen for a fuel cell is produced - for example, from hydrocarbon fuels, or through electrolysis of water using electricity generated from fossil fuels - there can be some pollutants associated with the fuel production. If the hydrogen is generated from renewable resources, like solar or wind-generated electricity for use in electrolysis, then the entire system is pollution-free and renewable. Although there are pros and cons with each of these methods, they are all being carefully considered and developed.

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Technology

Fuel cells generate electricity, using hydrogen as their fuel in an electrochemical process. A fuel cell can be used, in combination with an electric motor, to drive a vehicle – quietly, powerfully and cleanly.

An individual fuel cell consists of two electrodes, one positively charged (cathode) and one negatively charged (anode), with a substance that conducts electricity (electrolyte) sandwiched between them. Oxygen from the air passes over the cathode and hydrogen over the anode, generating electricity and water. The hydrogen fuel for a fuel cell EV can be supplied in several ways. Some vehicles carry a tank of pure hydrogen. Others could be equipped with a "fuel reformer" that converts hydrocarbon fuels—such as methanol, natural gas, or gasoline—into a hydrogen-rich gas. Individual fuel cells must be combined into groups called fuel cell stacks in order to achieve the necessary power required for motor vehicle applications

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Facts

- Fuel cell vehicles have the potential to strengthen our national energy security by reducing our dependence on foreign oil. The U.S. uses about 20 million barrels of oil per day, at a cost of about $2 billion a week. In fact, half of the oil used to produce the gasoline you put in your tank is imported.
- Fuel cells can provide much more electric power than the 12-volt batteries in conventional automobiles. Therefore, FCVs can be equipped with more sophisticated and powerful electronic systems than those found in conventional gasoline vehicles. For example, some vehicle manufacturers are designing vehicles that use electronic steering and braking. Eliminating the steering column and wheel may make these vehicles safer.
- Internal combustion engines in automobiles convert less than 20% of the energy in gasoline into power that moves the vehicle. Vehicles using electric motors powered by hydrogen fuel cells are much more energy efficient, utilitizing 40-60% of the fuel's energy. Even FCVs that reform hydrogen from gasoline can use about 40% of the energy in the gasoline.
- The U.S. Department of Energy projects that if a mere 10% of automobiles nationwide were powered by fuel cells, regulated air pollutants would be cut by one million tons per year and 60 million tons of the greenhouse gas carbon dioxide would be eliminated. DOE projects that the same number of fuel cell cars would cut oil imports by 800,000 barrels a day — about 13 percent of total imports.

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Safety

Fuel cell vehicles will be developed with levels of safety, comfort, and cost comparable to those of a conventional vehicle. Meeting consumers' cost expectations, especially when the vehicles are introduced will be difficult. But incentives, rebates, and possible auto manufacturer price adjustments will help to reduce the purchase price of these vehicles.

Like all fuels, hydrogen has energy and needs to be treated with respect. Because hydrogen is lighter than air it disperses very quickly. Manufacturers are committed to building fuel cell vehicles that meet or exceed safety standards.

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FEATURED VEHICLE

ubaru Legacy L Sedan/35th Anniv. Ed.

MORE INFO

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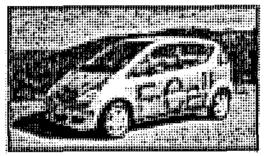
DID YOU KNOW?

he United States consumes 106 barrels of oil very second - and 65 percent of all oil is sed for transportation.

CLEAN VEHICLE SEARCH

SEARCH RESULT:

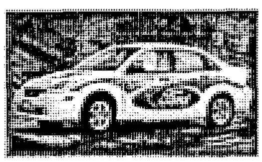


2002 Daimler Chrysler F-Cell (A-class)

Starting at the end of 2003, a fleet of 60 F-Cell vehicles will start to change the face of city streets in Japan, Singapore, Germany and the USA. The aims of this world-wide field trial are to further develop the technology to a volume production level by seeing how the vehicles perform under real-world conditions, and to establish what the infrastructure requirements will be.

Emission Rating:
ZEV

MORE INFO

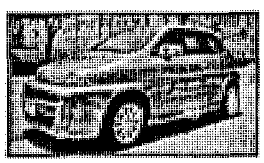


2002 Ford Focus FCV

The Ford Focus FCV fuel cell system is efficient, quiet, and produces zero emissions. Ford has announced plans to have a three year demonstration program of 5-10 fleet vehicles in Vancouver, Canada in 2004. Plans for 40 fleet vehicles introduction in Germany and California in 2004.

Emission Rating:
ZEV

MORE INFO



2003 Honda FCX Fuel Cell

Honda is delivering a family of new FCX fuel-cell vehicles to its first customer, the city of Los Angeles. Honda plans to lease approximately 30 fuel-cell cars in California and Japan during the next several years. The fuel-cell itself is propelled by electricity generated by a hydrogen-oxygen chemical reaction—and its only emission, remarkably, is water vapor.

Emission Rating:
ZEV

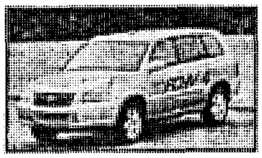
MORE INFO

2002 Nissan X-TRAIL

Nissan will deliver its first commercial fuel cell vehicle in 2003. The X-TRAIL was approved by the Japanese Minister of Land, Infrastructure and Transport for public road testing, which will start in early 2003, along with limited marketing later in the year.

Emission Rating:
ZEV

MORE INFO



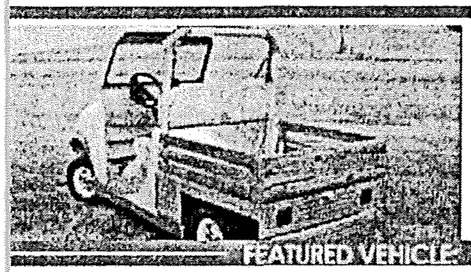
2004 Toyota Fuel Cell Hybrid Vehicle(FCHV)

Emission Rating:
ZEV

Its only exhaust is water vapor. A hydrogen fuel cell that harnesses the electricity of separated atoms and molecules as they strive to be electrically balanced. Developed entirely in-house, FCHV-4 shows Toyota on the leading edge of fuel-cell technology. Three FCHVs have been leased to UC Irvine, 3 to UC Davis, and 4 to Japanese government agencies for 30 months at $10,000/month each.

MORE INFO

BACK TO VEHICLE SEARCH



.afayette County Car Company LC3 Utility

MORE INFO

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CLEANER GAS CARS

INTRODUCTION | ENVIRONMENTAL BENEFITS | PERKS AND CONVENIENCES
TECHNOLOGY | PZEV WARRANTIES | SMOG CHECKS | FACTS

VEHICLE SEARCH

)ID YOU KNOW?

f all family vehicles in the United States were ned up bumper to bumper, they would reach rom the Earth to the moon - and back.

Introduction

While all California cars have advanced emission control systems, many new gasoline vehicles are designed to produce extremely lower levels of emissions. These vehicles are rated Partial Zero Emission Vehicles, or PZEVs by the California Air Resources Board. PZEVs are so clean because they meet the ARB's most stringent tailpipe emission standard - Super Ultra Low Emission Vehicle, and have a 15 year/150,000 mile warranty and zero evaporative emissions.

Environmental Benefits

Gasoline vehicles with a PZEV rating are mass-produced in a variety of makes and models and are available to the public today. They have an immediate impact on air quality because they are popular models at affordable prices. In addition, the extended warranty provides you with the added security that your vehicle will be maintained for a longer period of time. The zero evap and warranty requirements make PZEV emissions similar to the upstream emissions associated with ZEVs.

BACK TO TOP

Perks and Conveniences

Nothing new here - just a much cleaner version of the conventional internal combustion engine vehicle. In many instances a car buyer may pay only $100 more for a cleaner vehicle model that comes with a better warranty. It is even possible to be driving a clean car and not even know it!

BACK TO TOP

Technology

Automakers are continually finding new technologies that improve their vehicles. Tremendous benefits have resulted alone by industry's ability to simplify, refine, and reduce the costs of their emission control systems. PZEVs are primarily four cylinder engines, however there are some five and six cylinder models available. Many PZEVs utilize various combinations of multiple catalysts, several oxygen sensors, exhaust gas recirculation, and an air pump.

To meet PZEV standards, vehicles may have conventional catalyst systems enhanced by greater loading and an integral hydrocarbon adsorber. A linear oxygen sensor may also be applied for better fuel control along with retarded timing and electric air injection at cold start

To meet the zero fuel-evaporative emission requirement, vehicle fuel systems will likely incorporate an additional trap on the canister vent as well as a carbon trap on the engine air inlet. Improved seals at all junctions or joints in the fuel and vapor recovery hoses may be needed to mimimize fuel leakage. Better materials, either steel or improved plastics, will prevent permeation and provide greater durability. Fuel system components will likely be consolidated, such as incorporating the fuel pump and possibly the canister, within the fuel tank, to minimize junction and joints that could lead to fuel leakage.

Warranties on PZEVs and AT PZEVs
In order for a vehicle to receive an emissions rating of PZEV or AT PZEV, the manufacturer must guarantee a full warranty on all emissions related parts of the vehicle for 15 years or 150,000 miles (Exception: the traction battery in some hybrid vehicles may be covered for only 10 years). This warranty is transferrable with the vehicle, and ensures that the car will run clean for most of it's life.

"Emissions-related part" means any automotive part, which affects any regulated emissions from a motor vehicle which is subject to California or federal emissions standards. In simple terms, any component failure that causes a vehicle's "Check Engine" light to illuminate is covered by the manufacturer. The customer, however is expected to maintain the vehicle as recommended by the manufacturer.

Examples of parts that may affect a vehicle's emissions may be found in the Emissions-Related Parts List, adopted by the (CA) State Board on November 4, 1977, as last amended May 19, 1981.

Smog Checks
Even though PZEVs and AT PZEVs have warranty coverage for emission related problems, they are still required to receive smog checks, just as any non-PZEV would.

Facts about PZEVs

- There are 27 PZEV models in 2004. It is estimated that 140,000 PZEVs will be on California roads this year - reaching 700,000 more each year by 2011 in CA alone.

- BMW, Ford, Volvo, Toyota, Honda, Subaru, Hyundai, Mitsubishi, Nissan and Volkswagen all have several PZEV models available to consumers.

- Cars with a PZEV emissions rating have such tight pollution controls, and the burning of fuel is so complete, that in very smoggy urban areas, exhaust out of the tailpipe can actually be cleaner than the air outside.

- Gasoline vehicles meeting PZEV emissions standards sometimes have even lower emissions than hybrid or alternative fuel vehicles.

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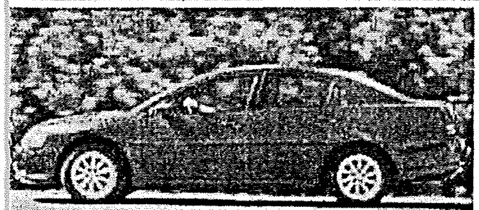

FEATURED VEHICLE

Mitsubishi Galant DE and ES 2.4L

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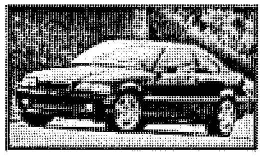
DID YOU KNOW?

The state's more than 18 million automobiles consume more than 14 billion gallons of gasoline each year – enough gasoline to fill a line of tanker trucks stretched bumper to bumper from San Francisco to San Diego and back.

CLEAN VEHICLE SEARCH

SEARCH RESULT:

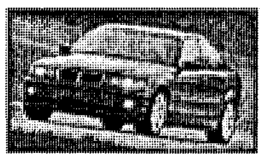


2004 BMW 325Ci Coupe

With a boldly updated kidney grille, headlights and air intake, the 325Ci states its true intentions up front. Thanks to its tuned sport suspension and a smooth-revving 184-hp inline six, it transforms curves into wide smiles and on-ramps into exclamation points.

Emission Rating:
PZEV

MORE INFO



2004 BMW 325i Sedan

The BMW 325i sport luxery sedan is under $28k. It's 184-hp engine and silky 5-speed transmission supply a powerband that's as wide as it is exhilarating. Immense 4-wheel disc brakes with DBC deliver peerless stopping power, while advanced safety systems remind you that some BMW features are simply invaluable.

Emission Rating:
PZEV

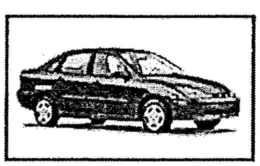
MORE INFO

2004 BMW 325i Sports Wagon

With 184-horsepower in front and up to 57 cu. ft. in back, the 325i sport wagon is engineered to thrill adventure seekers. A 5-speed transmission and specially tuned suspension reward enthusiasts gear after gear, corner upon corner. The 325i sport wagon is rated a partial zero emission vehicle (PZEV) by the California Air Resources Board. PZEVs have no evaporative emissions - which means they have fewer emissions while being driven than a typical gasoline car has while just sitting.

Emission Rating:
PZEV

MORE INFO



2004 Ford Focus LX

The Focus that fits any budget. The Focus PZEV features a new 2.3L engine that produces more power than the current base engine, and it emits "zero" gasoline evaporative emissions from the fuel system.

Emission Rating:
PZEV

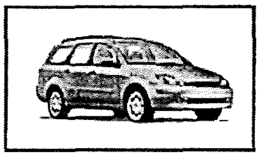
MORE INFO

2004 Ford Focus SE Sedan

Spirited and nicely equipped. The Focus PZEV features a new 2.3L engine that produces more power than the current base engine, and it emits "zero" gasoline evaporative emissions from the fuel system.

Emission Rating:
PZEV

MORE INFO

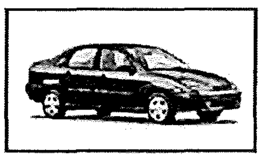


2004 Ford Focus SE Wagon

The Focus for the family. The Focus PZEV features a new 2.3L engine that produces more power than the current base engine, and it emits "zero" gasoline evaporative emissions from the fuel system.

Emission Rating:
PZEV

MORE INFO

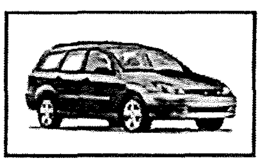


2004 Ford Focus ZTS Sedan

Powerful sports sedan. The Focus PZEV features a new 2.3L engine that produces more power than the current base engine, and it emits "zero" gasoline evaporative emissions from the fuel system.

Emission Rating:
PZEV

MORE INFO

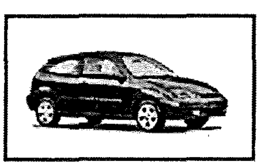


2004 Ford Focus ZTW Wagon

The wagon with something more. The Focus PZEV features a new 2.3L engine that produces more power than the current base engine, and it emits "zero" gasoline evaporative emissions from the fuel system.

Emission Rating:
PZEV

MORE INFO

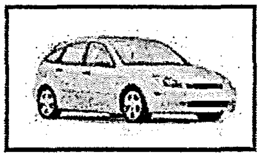


2004 Ford Focus ZX3

Three doors and great versatility. The Focus PZEV features a new 2.3L engine that produces more power than the current base engine, and it emits "zero" gasoline evaporative emissions from the fuel system.

Emission Rating:
PZEV

MORE INFO

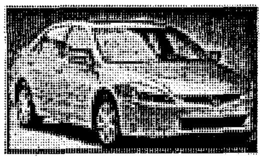


Emission Rating:
PZEV

2004 Ford Focus ZX5

Five doors and lots of room. The Focus PZEV features a new 2.3L engine that produces more power than the current base engine, and it emits "zero" gasoline evaporative emissions from the fuel system.

MORE INFO

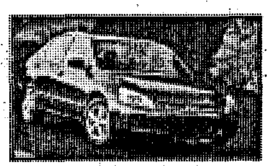


Emission Rating:
PZEV

2004 Honda Accord EX Sedan

The Accord EX Sedan provides an extra level of refinement and comfort. Inside, you'll find standard front side airbags, an AM/FM/6-disc in-dash changer and 6 speakers, steering-wheel-mounted audio controls, premium interior trim, ambient console lighting and a driver's seat with power height adjustment. Outside, there are 16" alloy wheels, 4-wheel disc brakes with electronic brake distribution and a power moonroof with tilt feature.

MORE INFO

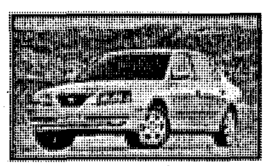


Emission Rating:
PZEV

2004 Honda Accord LX Sedan

For the ultimate combination of performance and value, the Accord LX Sedan should be at the top of everyone's list. In addition to the DX features, there's a remote entry system with power window control, air conditioning, cruise control, power mirrors and door locks, and another 4 speakers for the AM/FM/CD audio system. Also available are side airbags.

MORE INFO

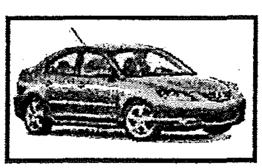


Emission Rating:
PZEV

2004 Hyundai Elantra GLS 2.0L

The compact Elantra is Hyundai's best-selling model in the U.S. The 2004 Elantra is available with a SULEV rated 2.0-liter, four cylinder engine that qualifies as a PZEV.

MORE INFO

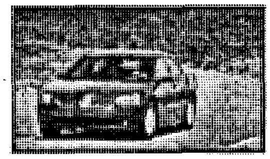


2004 Mazda MAZDA3

The MAZDA3 is Mazda's newest vehicle, replacing the popular Protege and Protege5 sedan and sport wagon. MAZDA3 offers high quality, aggressive styling, and the Zoom-zoom driving experience, all in a package that's affordable to purchase and economical to operate.

Emission Rating:
PZEV

MORE INFO

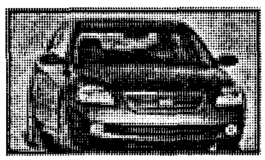


2004 Mitsubishi Galant DE and ES 2.4L

The all-new 2004 Galant is a mid-sized, four-door sedan with enhanced style, roominess, and performance. All DE and ES 2.4L models sold in California meet the ARB's stringent emission rating of PZEV.

Emission Rating:
PZEV

MORE INFO

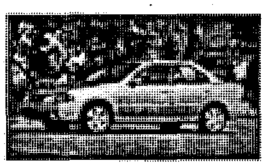


2004 Nissan Altima 2.5, 2.5S or 2.5SL

The 2004 Altima brings to the segment a blend of performance, style and value that is unmatched. With its distinctive exterior design, powerful 4-cylinder engine, performance-oriented suspension and class-leading roominess, Altima injects passion into the driver with a robust performance and offers an escape from the traditional four-door sedan.

Emission Rating:
PZEV

MORE INFO

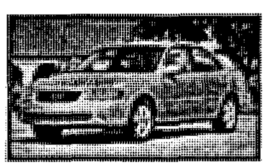


2004 Nissan Sentra 1.8

In a Sentra, the thrill of driving is very much alive. The Sentra has a responsive independent-strut front suspension and the road-gripping influence of a Multi-Link Beam™ rear suspension.

Emission Rating:
PZEV

MORE INFO

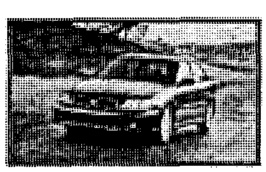


2004 Nissan Sentra 1.8S

In a Sentra, the thrill of driving is very much alive. The Sentra has a responsive independent-strut front suspension and the road-gripping influence of a Multi-Link Beam™ rear suspension.

Emission Rating:
PZEV

MORE INFO



2004 Subaru Legacy 2.5 GT Sedan

Sleek, aerodymanic, and truly unique, the Legacy 2.5 GT Sedan combines luxery and style with high performance.

Emission Rating:
PZEV

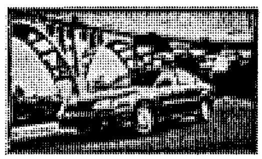
MORE INFO

2004 Subaru Legacy 2.5 GT Wagon

The Legacy 2.5 GT Wagon offers the discerning driver the highest level of comfort, style, and space for an unprecedented driving experience.

Emission Rating:
PZEV

MORE INFO



2004 Subaru Legacy L Sedan/35th Anniv. Ed.

The Legacy L 35th Anniversary Edition is one of the best automotive values on the road today. Choose the sedan or wagon model and get loads of extras - all for a price that seems like a gift.

Emission Rating:
PZEV

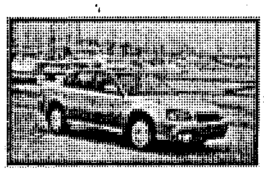
MORE INFO

2004 Subaru Legacy L Wagon/35th Anniv. Ed.

The Legacy L 35th Anniversary Edition is one of the best automotive values on the road today. Choose the sedan or wagon model and get loads of extras - all for a price that seems like a gift.

Emission Rating:
PZEV

MORE INFO

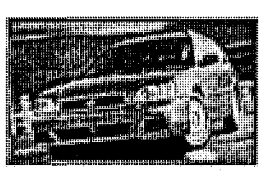


2004 Subaru Legacy Outback Limited Sedan

The Outback Limited Sedan combines the classic lines and styling of a sports sedan with the versatility and control of hte Full-Time All-Wheel-Drive Outback wagon.

Emission Rating:
PZEV

MORE INFO

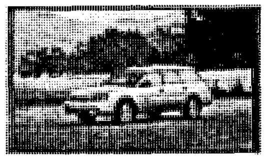


2004 Subaru Legacy Outback Limited Wagon

Be tough and go places you never thought you would go! Rugged yet sophisticated in the 2004 Outback Limited Wagon captures the perfect blend of car-like handling and sport-utility performance.

Emission Rating:
PZEV

MORE INFO



2004 Subaru Legacy Outback Wagon

Be tough and go places you never thought you would go! Rugged yet sophisticated, the 2004 Outback captures the perfect blend of car-like handling and sport-utility performance.

Emission Rating:
PZEV

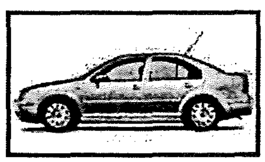
MORE INFO

2004 Toyota Camry LE, SE or XLE

The Camry treats you to a ride that's comfortable, quiet and smooth, even when the road conditions aren't. Each one has an impressive collection of features, including recent additions like a power driver's seat, now standard on the LE and SE models.

Emission Rating:
PZEV

MORE INFO

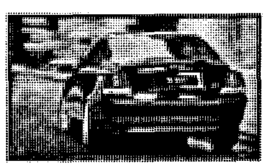


2004 Volkswagen Jetta Sedan GL or GLS 2.0L

The 2004 Jetta Sedan benefits from a simple and true design. It's compact, pretty lightweight, and requires less space under the hood - all of which goes to providing smooth engine performance and lowered emissions.

Emission Rating:
PZEV

MORE INFO

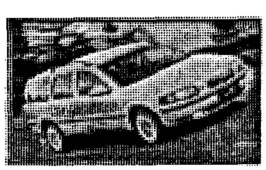


2004 Volvo 2.4 S60 Sedan

The Volvo S60's engine is crafted of lightweight aluminum and feature Volvo's latest low-friction technology for good fuel efficiency while providing excellent overall performance. Continuously variable valve timing (CVVT) and three-way catalytic converters allow the S60 to meet or exceed stringent emission standards.

Emission Rating:
PZEV

MORE INFO



2004 Volvo 2.4 V70 Wagon

The Volvo S60's engine is crafted of lightweight aluminum and feature Volvo's latest low-friction technology for good fuel efficiency while providing excellent overall performance.

Emission Rating: PZEV	Continuously variable valve timing (CVVT) and three-way catalytic converters allow the S60 to meet or exceed stringent emission standards.

MORE INFO

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Light-Duty Hybrids Available Now & in Immediate Future:*

	Toyota Prius Gen 1	Honda Civic	Honda Insight	Ford Escape	GM Silverado & Sierra, Gen 1	Toyota Prius Gen 2
Model Year	2003	2003	2003	2005	2004	2004
EPA Size Class[1]	Compact Sedan	Compact Sedan	Two seater	Compact SUV	Fullsize Pickup	Midsize Sedan
EPA Adjusted MPG City/Hwy[2]	52/45	48/47	57/56	35-40/30	Around 18	59/51[16]
Combined MPG[15]	48.85	47.55	56.55	35.5	Around 18	55.4
Hybrid Technology:						
Idle Turn Off	Idle Turn Off[9]	Idle Turn Off[7]	Idle Turn Off[8]	Idle Turn Off[1]	Idle Turn Off[1]	Idle Turn Off[10]
Regenerative Braking	Regenerative Braking[9]	Regenerative Braking[7]	Regenerative Braking[8]	Regenerative Braking[1]	Minimal Regen Braking[1]	Regenerative Braking[10]
Electric Only Drive	Electric Only Drive[9]	No[7]	No[8]	Electric Only Drive[1]	NO	Electric OnlyDrive[10]
Drivetrain Type[3]	Series/Parallel	Parallel	Parallel	Series/Parallel	Parallel	Series/Parallel
Downsized Engine	Downsized Engine[9]	Downsized Engine[7]	Downsized Engine[8]	Downsized Engine[1]	NO	Downsized Engine[10]
Emissions:						
Rating[4] (Select Availability)	SULEV	SULEV	SULEV	SULEV/AT-PZEV		SULEV/AT-PZEV
Rating[4] (Nat'l Availability)	ULEV	ULEV	LEV, BIN 5			Tier 2, Bin 3
EPA Air Pollution Score[5]	7 ULEV; 10 SULEV	7 ULEV	6 LEV; 8 BIN 5; 10 SULEV			
Annual Tailpipe CO2[18]	5,944 lbs	6,107 lbs	5,135 lbs	As low as 8,180 lbs	Around 16,133 lbs	5,242 lbs
Annual CO2 Emissions[6]	7,369 lbs	7,571 lbs	6,366 lbs	As low as 10,141 lbs	Around 20,000 lbs	6,498 lbs
Total Annual GHG Emissions[1, a]	6 tons	6 tons	5 tons			
Power						
Gas Engine[1]	4 cyl; 1.5L; 70hp[9]	4 cyl; 1.3L; 85hp[7]	3 cyl; 1.0L; 65hp[8]	4 cyl; 2.0L; 130hp[1]	8 cyl; 5.3L; 285hp (est.)[11]	4 cyl; 1.5L; 78hp[10]
Electric Motor	44hp[9]	13.4hp[7]	13.4hp[8]	87hp[1]		67hp[10]
Est. Combined hp	98hp[9]	93hp[7]	71hp[8]	200hp[1]		106hp[10]
Battery	274V Ni-MH[9]	144V Ni-MH[7]	144V Ni-MH[8]	300V Ni-MH[1]	36V lead-acid[1]	Ni-MH
CLEAR ACT (S. 505)						
Technology Tax Credit[17]	>30%; $1000	10%-20%; $500	10%-20%; $500	>30%; $1000		>30%; $1000
Performance Tax Credit[17]	$1500	$1500	$1000	$1500		$2000
Other Notes	1st HEV to be mass produced; the HEV of choice in fleets		Ultra-lightweight aluminum body		Generator capabilities[1] Integrated starter generator system	"drive-by-wire" (more electronic systems, less mechanical)

*This chart includes the best available information to date based on automaker announcements. Actual delivery dates and specifications of any of the models discussed here are subject to change.

	Saturn VUE	Lexus RX330[16]	Toyota Highlander[16]	Toyota Sienna[16]	Dodge Ram[16]	Chevrolet Equinox[16]	Ford Futura
Model Year	No longer scheduled for release	2005	2005	2005	2005 (?)	2007	2006 - tbd
EPA Size Class[1]	Compact SUV	Compact SUV	Midsize SUV	Minivan	Full-size Pickup	Compact SUV	Midsize Sedan
EPA Adjusted MPG City/Hwy[2]	Up to 40	Up to 40			Up to 18		
Combined MPG[15]	Up to 40	Up to 40			Up to 18		
Hybrid Technology:							
Idle Turn Off		Idle Turn Off	Idle Turn Off	Idle Turn Off	Idle Turn off	Idle turn off	
Regenerative Braking	Regenerative Braking[14]	Regenerative Braking	Regenerative Braking	Regenerative Braking	Minimal Regen Braking	Regenerative Braking	
Electric Only Drive	Electric Only Drive[1]	Electric Only Drive	Electric Only Drive	Electric Only Drive	NO		
Drivetrain Type[3]	Likely Series/Parallel and/or Split[16]	Series/Parallel & Split	Parallel	Parallel	Parallel	Parallel	
Downsized Engine	Downsized Engine[1]	Downsized Engine	Downsized Engine	Downsized Engine	NO	NO	
Emissions:							
Rating[4] (Select Availability)	SULEV, likely AT-PZEV	SULEV/AT-PZEV expected	SULEV/AT-PZEV expected	SULEV/AT-PZEV expected			
Rating[4] (Nat'l Availability)							
EPA Air Pollution Score[5]							
Annual Tailpipe CO2[18]	As low as 7,260 lbs	As low as 7,260 lbs			As low as 16,133 lbs		
Annual CO2 Emissions[6]	As low as 9,000 lbs	As low as 9,000 lbs			As low as 20,000 lbs		
Total Annual GHG Emissions[1, a]							
Power							
Gas Engine[1]	4 cyl; 2.0L; 25hp[1]					4 cyl; 2.2L	
Electric Motor	Two-25hp motors[1]						
Est. Combined hp							
Battery	300V Ni-MH (est)[16]		Ni-MH	Ni-MH	36V lead-acid	36V lead-acid	
CLEAR ACT							
Technology Tax Credit[17]							
Performance Tax Credit[17]							
Other Notes	Expected to be quicker than	Gas engine for FWD; two separate electric			Up to 20 kW generator	Belt starter generator	

conventional Saturn Vue[1] | motors to power front/rear wheels[1] | capabilities[1] | system system

	GM Silverado/Sierra & Tahoe/Yukon, Gen2[16]	Chevrolet Malibu[16]	Ford Explorer[16]	Toyota Camry[16]	Dodge Durango[16]
Model Year	2007	2007	Cancelled	???	Currently shelved
EPA Size Class[1]	Fullsize Pickup	Midsize Sedan	Midsize SUV	Midsize sedan	Mid Size SUV
EPA Adjusted MPG City/Hwy[2]	Potentially over 20	Around 27 mpg			22-30
Combined MPG[15]	Potentially over 20				Up to 30
Hybrid Technology:					
Idle Turn Off	Idle Turn Off[1]	Idle off	Idle Turn Off[1]	Idle Turn Off	
Regenerative Braking	Minimal Regen Braking[1]	Minimal Regen Braking	Minimal Regen Braking	Regenerative Braking	Regenerative Braking
Electric Only Drive	NO		NO	Electric Only Drive	Electric Only Drive
Drivetrain Type	Parallel	Parallel	Parallel	Parallel	Split
Downsized Engine	NO	NO	NO	Downsized Engine	Downsized Engine
Emissions:					
Rating[4] (Select Availability)				SULEV/AT-PZEV expected	
Rating[4] (Nat'l Availability)					
EPA Air Pollution Score[5]					
Annual Tailpipe CO2[18]		Around 10,755 lbs			As low as 13,200 lbs
Annual CO2 Emissions[6]		Around 13,333 lbs			As low as 16,364 lbs
Total Annual GHG Emissions					
Power					
Gas Engine	8 cyl; 5.3L; 285hp (est.)[11]				6 cyl; 3.9L; 175hp
Electric Motor					72hp
Est. Combined hp					
Battery	??	36V lead acid	36V lead-acid	Ni-MH	
CLEAR ACT					20%-30%; $750
Technology Tax Credit[17]					
Performance Tax Credit[17]					
Other Notes	Generator capabilities Integrated starter generator system	Belt starter generator system	Integrated starter generator system		

Other possible vehicles in the 2005-2010 timeframe with very little detail[16]:

Ford: Ford Freestyle crossover utility vehicle, Mercury and Mazda versions of the Escape, Ford Focus, Mercury Montego midsize luxury, Volvo XC90 mid-size SUV.

DaimlerChrysler: Chrysler Sebring midsize sedan, Dodge Caravan

Honda: Accord midsize sedan, Acura midsize sedan, Odyssey minivan, Pilot midsize SUV.

Nissan (using Toyota technology): Altima midsize sedan, Quest minivan

Abbreviations:
Ni-MH – nickel metal hydride
LEV[12] – Low Emission Vehicle: weakest emission standard in California; 50% reduction in particulates and 66% reduction in nitrogen oxides compared to federal Tier II standard
ULEV[12] – Ultra Low Emission Vehicle: 50% reduction in carbon monoxide when compared to LEV standard
SULEV[12] – Super Ultra Low Emission Vehicle: 50% reduction in carbon monoxide and 70% reduction in nitrogen oxides when compared to ULEV standard
PZEV[13] – Partial Zero Emission Vehicle: same emissions standard as SULEV, but qualifying car must also have near-zero evaporative emissions and emissions control system must come with 150,000 mile/15 year warranty

Notes
1. DeCicco, John, and James Kliesch. ACEEE's Green Book: The Environmental Guide to Cars & Trucks. American Council for an Energy-Efficient Economy. Washington, DC: 2003.
2. MPG City/Hwy is for automatic and CVT (continuously variable transmission) models.
3. Drivetrain classifications from UCS report: Friedman, David. A New Road: The Technology and Potential of Hybrid Vehicles. Union of Concerned Scientists. Cambridge, MA: 2003.
4. Emission Ratings & Availability:
    Select: Vehicles are primarily available from dealers in CA, MA, ME, NY, VT and contiguous states including AZ, CT, NH, NJ, NV, OR, PA, RI.
    National: Vehicles are generally available everywhere in the U.S. http://www.fueleconomy.gov/feg/hybrid_sbs.shtml http://www.epa.gov/autoemissions/all-rank-03.htm
5. vehicles are rated on a scale of 0-10 (10 being the cleanest) according to pounds of smog-forming pollution per 15,000 miles.
   http://www.fueleconomy.gov/feg/hybrid_sbs.shtml http://www.epa.gov/autoemissions/all-rank-03.htm
6. Annual CO2 Emissions calculated using (15,000 miles/year) / (Combined MPG) x (24 pounds CO2/gallon). (includes upstream CO2 emissions and end-user CO2 emissions)
   David Friedman, Senior Engineer, Union of Concerned Scientists: personal communication 7/25/2003
7. http://www.hondacars.com/models/model_overview.asp?ModelName=Civic+Hybrid
8. http://www.hondacars.com/models/model_overview.asp?ModelName=Insight
9. http://www.toyota.com/html/shop/vehicles/prius
10. http://www.auto123.com/en/info/news/previews.view.Toyota.spy?artid=13861&pg=1
11. http://www.chevrolet.com/silverado
12. www.dieselnet.com
13. www.arb.ca.gov/msprog/ccbg/atpzev.htm
14. http://www.saturnfans.com/Cars/Future/hybridvue.shtml
15. Combined MPG based on 55% city driving & 45% highway driving http://www.environmentaldefense.org/tailpipetally/
16. David Friedman, Senior Engineer, Union of Concerned Scientists: personal communication 7/25/2003
17. Tax credit figures derived from the CLEAR ACT (Senate Bill 505, 108th Congress) as drafted on March 4, 2003 http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=108_cong_bills&docid=f:s505is.txt.pdf
18. Tailpipe CO2 emissions calculated using (15,000miles/year)/(combined mpg) x (19.36 pounds CO2/gallon) (only includes CO2 emitted from automobile tailpipe) - Lisa Snapp, EPA personal communication 8/5/2003

a. Greenhouse gas emissions measured in tons per year. These figures include embedded GHG emissions (those emitted during production of the vehicle), upstream GHG emissions (those emissions associated with the refining and transporting of gasoline), and end-user GHG emissions (those GHGs that actually leave the tailpipe of the car during driving). The gases included in this measurement are converted to a CO_2 equivalent (according to their "efficiency" in warming the atmosphere), and include carbon dioxide, hydrocarbons, nitrogen oxides, nitrous oxide, methane, and carbon monoxide.

Emission Reduction Analysis for Maine

from

California Low Emission Vehicle Program
and
Zero Emission Vehicle Program

Maine Department of Environmental Protection
February 2004

"Comparing the Emission Reductions of the LEV Program to the Tier 2 Program"

- NESCAUM commissioned study
- Analysis conducted by Cambridge Systematics
- Study published October 2003
- Four variations of the ZEV mandate evaluated

Applicability to Other States

- “While absolute daily emissions reductions were calculated for three of the four Northeast LEV states, similar benefits - in percentage reduction terms - would be expected for any other state choosing to adopt this program in lieu of federal standards”

Annual Emission Benefits of the LEV 2 Program in 2020

State	HC Reduced (tons)	% HC Reduction Over Tier 2	Toxics Reduced (tons)	% Toxics Reduction Over Tier 2	CO2 Reduced (tons)	% CO2 Reduced
NY	10,020	15	502	25 for each toxin	2,500,000	2.25
MA	3,300	17	185	25 for each toxin	900,000	2.25
VT	510	14	29	19 for each toxin	120,000	2.25
Total	13,830	15.3	716	23 for each toxin	3,520,000	2.25

LEV versus ZEV Reductions

- Approximately 30 percent of the additional hydrocarbon benefit estimated for the California LEV program is a consequence of the ZEV mandate (with the remaining 70 percent coming from more stringent evaporative and tailpipe standards)

Analysis Assumptions

- Light duty vehicles (less than 6,500 pounds)
- ZEV begins in 2005 (synchronized with California in MY 2007)
- Massachusetts sales mix used for the Vermont analysis
- No IM program inputs in Vermont
- Benefits of the 150,000-mile standard not estimated
- Vermont VMT extrapolated from historical data and allocated by vehicle type (same as Mass)

VMT Estimates (daily, in million miles) 2020

	LDV	LDT1	LDT2	Total
Vermont	7.7	11.5	3.8	23.0
Maine *	13.2	4.8	16.0	34.1

Ratio of Maine VMT to Vermont: 1.48

*Maine data based on DOT VMT projections and EPA vehicle mix projections

Maine Hydrocarbon Reductions From LEV and ZEV Programs

- Vermont Reductions 510 tons annual (2020)
- Maine Reductions 755 tons annual (2020)
- Maine Reductions-LEV (70%) 528 tons
- Maine Reductions-ZEV (30%) 226 tons

Zero Emission Vehicle Program

- Conventional Path
- 2% ZEV
- 2% AT PZEV
- 6% PZEV

- Alternative Compliance Path
- Meet entire 10% ZEV with ATPZEVs and PZEVs
- Supply 250 ZEVs (2005-2008) of which half must be Fuel Cell Vehicles

According to California Resources Board web site

Zero Emission Vehicle Classification Definitions

- **ZEV** (Zero Emission Vehicle) : pure electric or fuel cell vehicle
- **PZEV** (Partial Zero Emission Vehicle): 150,000 mile Super Low Emission Vehicle standard plus zero evaporative standard
- **AT PZEV** (Advanced Technology PZEV): Above PZEV rating plus use "ZEV-enabling clean" technology such as alternative fuel or electric drive (hybrid) system

Vehicle Availability
Model year 2004

- AT PZEVs
  - Honda Civic (cng)
  - Toyota Prius (hybrid)
- PZEVs
  - 13 manufacturers
  - 20 different models