Executive Summary

The world started down a new road in 1997 when the first modern hybrid electric car, the Toyota Prius, was sold in Japan. Two years later, the United States saw its first sale of a hybrid, the Honda Insight. These two vehicles, followed by the Honda Civic Hybrid, marked a radical change in the type of car being offered to the public: vehicles that bring some of the benefits of battery electric vehicles into the conventional gasoline powered cars and trucks we have been using for more than 100 years.

In the coming years, hybrids can play a significant role in addressing several of the major problems faced by the United States and the world today: climate change, air pollution, and oil dependence. Whether this new technology delivers on its promise hinges on the choices automakers, consumers, and policymakers make over the coming years. Poor choices could result in hybrids that fall short even of what conventional technology could deliver on fuel economy, emissions, or both.

This report provides consumers and policymakers with the tools they will need to sort out the many technological, financial, and environmental differences among the hybrids that will be brought to market in the coming years. Using new research into the cost and performance of hybrid technology, this report provides a comprehensive assessment of the technology, the fuel economy, and the costs associated with a fleet of passenger cars and trucks that rely on hybrid technology to more than double the fuel economy commonly available today. If they are designed well, these hybrids can equal or better the utility, comfort, performance, and safety we've come to expect, while saving us thousands of dollars at the gas pump.

Defining Hybrids

Hybrids have been defined in a variety of ways, few of which help in determining whether a particular model realizes the technology's potential. The checklist in Table ES-1 *(see page 2)* provides a reasonable method for evaluating which cars and trucks are hybrids and for differentiating among them based on their technologies. In general, hybrids with more checkmarks do more to provide energy security and less to harm the environment than those with fewer checkmarks. However, the most effective way to gauge a hybrid's energy security and environmental performance will be to evaluate their fuel economy and emissions performance directly on the road.[1]

On this checklist, the Insight and the Civic Hybrid each receives three checkmarks and are thus considered "mild" hybrids. With four checkmarks, the Prius is a "full" hybrid. A vehicle that receives five checkmarks is a "plug-in" hybrid, none of which are yet available in the United States. If a vehicle has only one checkmark it is actually just a conventional vehicle. Two checkmarks qualifies a vehicle as a muscle-hybrid, a vehicle that uses hybrid technology to increase power and performance instead of significantly increasing fuel

[1] The most appropriate method would combine the fuel economy and emissions level with weighting factors based on the health and economic effects of gasoline consumption and tailpipe emissions.

economy—leading to an expensive vehicle with very low cost-effectiveness. As more vehicles enter the market, this checklist can be used to evaluate the hybrids automakers offer.

The Technology's Potential

The Honda Civic Hybrid and Toyota Prius are good examples of the current potential of hybrids —but they're just a start. More technology is ready to be put to work and not only for compact cars. This study provides a broader picture of how hybrid technology could transform the whole passenger fleet both within this decade and into the next.

A fleet of cars and trucks that takes full advantage of hybrid and other advanced technologies could reach an average fuel economy of 60 mpg, as Figure ES-1 shows. Even conventional technologies could boost the passenger vehicle fleet average up to 40 mpg. And all the hybrids examined in this study can meet today's most stringent standards for tailpipe emissions[2] (excluding the zero-emissions standard). The study's key findings are outlined below.

- A fleet of passenger cars and trucks using conventional technology has the potential to reach a fleet average of 40 mpg. The average vehicle in this fleet will cost about $1,700 more in the showroom, but will save consumers $3,800 at the gas pump over the vehicle's 15-year life for a net savings of $2,100.
- A fleet of mild hybrids can reach nearly 50 mpg, with a retail price increase of about $2,900 by using advanced technologies available to automakers within this decade.[3] Lifetime gasoline savings will amount to $4,700, producing a net savings of $1,500 for the average driver when the cost of battery replacement is included.[4] Mild hybrids that use more moderate technology or smaller motor/battery systems will achieve lower fuel economy and will be less cost effective.[5]

Table ES-1 **Hybrid Checklist: Is This Vehicle a Hybrid?**

Does this vehicle...	Conventional Vehicle	Muscle Hybrid	Mild Hybrid	Full Hybrid	Plug-in Hybrid
Shut off the engine at stop-lights and in stop-and-go traffic	✓	✓	✓	✓	✓
Use regenerative braking and operate above 60 volts		✓	✓	✓	✓
Use a smaller engine than a conventional version with the same performance			✓	✓	✓
Drive using only electric power				✓	✓
Recharge batteries from the wall plug and have a range of at least 20 miles on electricity alone					✓

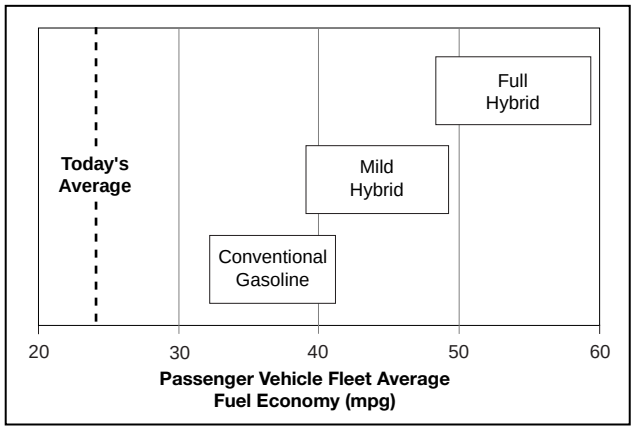
[2] The Federal Tier 2, Bin 2 standard (also California's SULEV standard).

[3] Advanced technology refers to engine, transmission, weight savings, and battery and motor technology that has already been developed by automakers, but has not found its way into the US fleet. Examples include the gasoline direct injection engine and batteries with power densities over 800 Watts per kilogram.

[4] Excludes vehicle taxes and other fees at purchase, tax credits or deductions, maintenance, and annual registration fees.

[5] Moderate technologies are available on cars and trucks today, but in limited volumes. Some examples include low-friction variable valve engines, continuously variable transmissions, and batteries with power densities of 600-700 Watts per kilogram.

Figure ES-1 **Fuel Economy Potential for Hybrid Electric and Conventional Vehicles**



NOTES:

1. The lower boundary is set by the use of moderate technology that is widely available during this decade. The upper bound is set by the use of more advanced technology that is likely to be available for wide use early in the next decade.

2. The mild hybrids are rated at 15% peak power from the motor and energy storage system, mild hybrids with lower peak power would not perform as well. Full hybrids with peak power below 25% will not perform as well as shown.

- Full hybrids using advanced technology are the key to a passenger car and truck fleet that approaches an average of 60 mpg. The average price increase for such vehicles is about $4,000 and the owners will save nearly $5,500 on gasoline over the life of the vehicle. Including battery replacement, consumers would see an average net savings of $900. Plug-in hybrids would realize even greater energy security and environmental gains, but with higher costs and lower net consumer savings.
- Using the advanced technologies available today is a key step to ensuring cost-effective hybrid options with good performance. If an automaker simply adds an electric motor and battery to the typical car or truck on the road today, the resulting vehicle will be more expensive and will not perform as well as the hybrids evaluated in this report.

In achieving higher fuel economy, future hybrids will not sacrifice safety. In fact, drivers of SUVs and pickups will be safer: battery placement in practical hybrid designs create a lower center of gravity, making SUVs and other tall vehicles less likely to tip over. And since they will be lighter, but just as strong as today, they will pose less danger to others during collisions, while keeping the SUV driver and passengers safe.

Hybrid Vehicles: Filling the Gap

This study emphasizes the role hybrids must play in our efforts to limit the contribution our cars and trucks make to US oil dependence, global warming, and local air pollution. In the short term, conventional technologies could quickly raise the average fuel economy of the passenger fleet to 40 mpg. Over the long term, we will have no choice but to adopt hydrogen fuel cells and other alternative fuel approaches. But these technologies will not be ready to replace the internal combustion engine in most new cars and trucks for over a decade.

Considering the slow turnover of the passenger vehicle fleet, this leaves a significant gap of ten to twenty years after the gains from conventional technology peak and before the promise of fuel cells will be fully realized. During that period, rising travel and increased car ownership will continue to drive us to import more and more oil from politically unstable countries and to add to global average temperature increases of 2.5 to 10.4°F by the end of the century. And the gains we will have made in air quality will begin to turn around due to rising travel and car ownership.

By filling this technological gap with well designed hybrid vehicles, passenger vehicle oil consumption and global warming emissions from cars and trucks can be reduced to below 1990 levels even before fuel cell technology makes its full impact.

As hybrids move into the marketplace, offering consumers additional choices, they also assure us that fleet average fuel economies of 50 to 60 mpg

can be achieved by the end of the next decade. At the same time, growing hybrid sales will bring down the cost of future hydrogen fuel cell vehicles, since they share many technologies, such as electric motors, power electronics, and energy storage.

Realizing the Promise

The role that hybrid vehicles can play is clear, but their success at filling this role is not guaranteed. Two key things are necessary to ensure that that they live up to their promise:

1. Hybrids with the best possible conventional and electric technology need to be made available to the public.
2. Production and sales of these hybrids need to reach mass-market levels in the hundreds of thousands per year.

These keys are in the hands of automakers, governments, and consumers.

Automakers hold the first key. With most of the necessary hybrid and conventional technology in their hands, they will be responsible for building the best possible hybrid vehicles and sending them to the showrooms. Automakers that try to graft hybrid technology onto today's conventional vehicles will end up producing expensive, low-performance vehicles better left in the research lab. The resulting lemons could tarnish the image of hybrid technology and discourage consumers.

Automakers that take the practical approach of putting the best available technology to work will provide consumers with "no compromise" vehicles. And they'll garner a profit as the vehicles reach mass-market production levels. By leading the industry, these automakers will create a sound footing for future profitability and a solid image of environmental and corporate responsibility.

Automakers also hold some responsibility for helping hybrids to reach mass-market levels. They will need to support hybrid sales by aggressively educating dealers, service personnel, and consumers about their products. But unless education and advertising campaigns are backed up with the good products, they will simply be false attempts at capturing a green image.

But automakers can't do it alone.

Government at all levels must act to help hybrids sell well during this decade if automakers are to reach the economies of scale necessary for hybrids to become profitable. A variety of tools can provide this support, such as regulations, including fleet purchase requirements, tax credits and other financial or nonfinancial incentives, and education programs. All these measures must be carefully crafted to assure that they provide support to hybrids in proportion to the energy security and environmental gains they offer. And they must acknowledge the extent to which hybrids help pave the way for hydrogen fuel cell vehicles.

Consumers also have a part to play in ensuring that hybrid sales reach mass-market levels. Assuming government and industry do their parts, this should not be a challenging task. Recent market studies indicate that at least 25% to 30% of con-sumers are already interested in purchasing a hybrid instead of a conventional vehicle. When they do, they will find themselves saving money over the life of their hybrid even as they do their part to reduce oil dependence and their impact on the environment.