Testimony of John German, Manager
Environmental and Energy Analyses
Product Regulator Office
American Honda Motor Company, Inc.
Before the
Subcommittee on Energy of the Committee on Science
U.S. House of Representatives
May 17, 2006

Good morning Madam Chairwoman and members of the Subcommittee. My name is John German and I am Manager of Environmental and Energy Analysis with American Honda Motor Company. We thank you for the opportunity to provide Honda's views on the subject of plug-in hybrid electric vehicles.

The automotive industry is in a period of unprecedented technology development, encompassing everything from gasoline engines and transmissions to diesels, hybrid-electric vehicles, fuel cells, and vehicles powered by alternative fuels. The efficiency of the conventional gasoline engine has improved by 1.5 to 2 percent per year for the last 20 years, although these gains have largely gone into features more highly valued by customers than fuel economy, such as performance, utility, luxury, and safety. Gasoline technology development is still proceeding rapidly, with variable valve timing, direct fuel injection, variable cylinder displacement, and turbocharging all on the horizon. Diesel engines have also seen dramatic improvement in recent years and manufacturers are working hard to meet the US emission standards. Hybrid-electric vehicles are in their 2nd and 3rd generation at Toyota and Honda and most other manufacturers have also or will be introducing hybrid-electric vehicles. Honda continues to market a dedicated compressed natural gas vehicle, the Civic GX, and is backing it with development of a home natural gas refueling system developed by Fuelmaker, called PHILL. A number of manufacturers produce flexible-fuel vehicles that run on gasoline or E85. Development of battery-electric vehicles continues and they have found a niche in neighborhood vehicles for closed communities. And, of course fuel cells are being heavily researched and developed. Different companies are working on different technologies, which is the optimal way and makes good use of competition.

Development of all technologies is accelerating in response to growing concerns about energy security and global warming. Global demand for transportation energy is so immense that no single technology can possibly be the solution. Fuel cells might be the final solution someday, but the challenges of hydrogen production, transport, and storage will take a long time to solve and implement, especially on the volume demanded for transportation worldwide. Biofuels are promising and can replace some fuel use, but even development of cellulosic ethanol only has the potential to displace, at most, 10 to 20 percent of the world's oil demand. The point is that there is no magic bullet – we are going to need rapid development and implementation of as many feasible technologies as possible. Honda is developing technology that meets both the needs of our customers and those of society. What was cutting edge one day can quickly become out dated. Thus we are constantly exploring a variety of technologies to achieve energy sustainability.

Given the rapid changes in technology, performance-based incentives are the best way to move the ball forward. It is impossible to predict the pace of technology development and when breakthroughs will or will not occur. Accordingly, technology-specific mandates cannot get us where we need to go. In fact, previous attempts to mandate specific technologies have a poor track record, such as the attempt to promote methanol in the 1990s and the California electric vehicle mandate. The primary effect of technology-specific mandates is to divert precious resources from other development programs that likely are much more promising. If there are to be mandates, they should be stated in terms of **performance** requirements, with incentives and supported by research and development.

With respect to plug-in hybrids, it is really too early in the development of hybrid vehicles and advanced batteries to predict whether plug-in vehicles will reach their hoped-for potential. Plug-in hybrids have a lot of promise, especially to displace oil consumption. They need and deserve further research and development. In that regard, the thrust of the draft legislation makes a good deal of sense. Before plug-in vehicles can be viable, however, there are a number of technology, consumer acceptance, environmental and cost issues that still need to be addressed.

A. Battery Weight and Size and Motor Performance Demands

The extra batteries add 175 to 500 pounds to the vehicle, which decreases performance, and it is difficult to find space for the extra batteries without detracting from the utility of the vehicle. Systems to plug the vehicle in to the electric grid must be safe and easy to use. Customer reaction to having to plug in the vehicle is largely unknown. Performance must be preserved, which means that either the electric motor and energy storage must provide performance equivalent to the engine; or the engine must be started and used with the electric motor for harder accelerations and higher speeds.

If the engine is not turned on for high accelerations, the vehicle is entirely dependent on the electrical system for acceleration. This requires a much larger electric motor and power electronics, which adds cost and weight and requires more cooling. The high electrical demand during high accelerations also generates high battery temperatures and accelerates battery deterioration. Adding an ultracapacitor to handle the high loads might solve the battery problem, but this adds yet more cost and takes up additional space.

If the engine is turned on only during high accelerations, emissions become a major issue. Catalytic converters are used to reduce most of the harmful emissions from the engine. However, these converters must be at least 350 degrees Centigrade (660 degrees Fahrenheit) to function properly. If the engine is off most of the time, catalyst temperatures will drop well below the level needed for conversion of emissions and tailpipe emissions will be orders of magnitude higher. Also note that current emission and fuel economy test procedures are not designed to accurately measure emissions from these types of vehicles and would have to be revised.

B. Energy Storage

However, while these are all legitimate issues that need further development, the issue of energy storage is the most significant. Some industry analysts have been critical of hybrids because they cost more and the fuel savings are not recoverable in the short term. Although current hybrid vehicles have relatively small battery packs, the battery pack is still the single largest cost of the hybrid system. Further, energy flow in conventional hybrids is carefully monitored and controlled to ensure maximum battery life. The battery state-of-charge is never allowed to rise above about 80% or drop below about 20%, where more deterioration occurs. Battery temperatures are carefully monitored at many points inside the battery pack and battery assist and regeneration is limited when necessary to keep the temperature at levels that ensure low deterioration. Also, the duty cycle of a conventional hybrid usually just changes the battery state-of-charge by a few percent of the total energy capacity. As a result of these efforts, the NiMH battery packs in current hybrid vehicles are expected to last the life of the vehicle.

The battery pack must be many times larger for a plug-in hybrid, even with just a 20-mile electric range. This adds thousands of dollars to the initial price of the vehicle, not to mention the impact the extra batteries have on weight and interior space. Further, the battery pack is now subjected to deep discharge cycles during electric-only operation and to much higher electrical loads and temperatures to maintain performance. This will cause much more rapid deterioration of the battery pack, likely requiring replacement of the battery pack at least once during the vehicle life.

The lithium-ion battery is being promoted by some as the answer to these challenges. Lithium-ion has the promise to increase energy and power density compared to NiMH, perhaps by as much as 100%, which would reduce the weight and size impacts. However, despite intense development of Lithium-ion batteries for many years, durability has not been proven, they are more susceptible to damage than NiMH, and they do not perform well in cold or hot environments. Additionally, Lithium-ion batteries are expensive and may not offer significant cost savings compared to NiMH batteries.

C. Cost Effectiveness Challenge

Let’s examine the real world economic problem posed by the battery storage issue using a specific example to help illustrate the issues. According to statements made by Mark Duvall of EPRI at the SAE Government/Industry Meeting on May 10, about 40% of the duty cycle of a plug-in hybrid should be electric-only operation. For a typical vehicle lifetime of 150,000 miles, this means that about 60,000 miles will be accumulated while the battery is being charge depleted. For a vehicle with an all-electric range of 20 miles, this requires that the battery pack be able to tolerate 3,000 deep discharge cycles without significant energy or power storage deterioration. Note that assumptions about the proportion of operation in charge-depleting mode directly affect the number of deep discharge cycles that the battery pack must be able to tolerate. For example, if the vehicle operates in charge-depleting mode 60% of the time, the battery pack will be used for 90,000 miles and it must be able to tolerate 4,500 deep discharge cycles or it will need to be replaced. 3,000 deep discharge cycles is the current goal for Lithium-ion batteries, but

it has not been proven yet, especially under the range of temperatures and operating conditions experienced in the real world.

For our example, let us assume that the starting point for a plug-in hybrid is the Toyota Prius. Real world fuel economy for the Prius is in the 45-50 mpg range. To be conservative, we will assume 45 mpg. Thus, for 150,000 miles, the Prius will use 3,333 gallons of fuel. If 40% of the mileage on the Prius is in charge-depleting mode, then the fuel savings will be 40% of 3,333 gallons, or 1,333 gallons.

Even at $3 per gallon, the fuel savings for a plug-in vehicle like the Prius is only $4,000 over the average vehicle lifetime. After factoring in the electricity cost to recharge the battery pack, which would be at least $1,000, the net savings to the consumer is less than $3,000. Even if the Lithium-ion battery meets all of its targets, the incremental cost of just the additional batteries in high volume applications would be close to the lifetime fuel savings. This ignores the tradeoff between electric motor size and emissions, the performance penalty from the additional weight of the batteries, the space needed for the batteries, the higher deterioration rate and increased risk of battery replacement due to the deep discharge cycles, and the cost of safe off-board charging systems. From a manufacturers' and customers' point of view, there is no business case unless fuel prices rises to substantially more than $3 per gallon, fuel shortages occur, plug-in hybrids are heavily subsidized, or there is a breakthrough in energy storage. By far the most important action the government can take is research into improved energy storage.

Until improved batteries can be developed with lower cost and better durability, there is little need to assess customer acceptability or conduct vehicle demonstration projects. However, customer discounting of fuel savings is a potential long-term barrier that eventually will need to be overcome. While some customers value fuel savings more highly, the average new vehicle customer only values the fuel savings for roughly his or her period of ownership, or about 50,000 miles. This means that, at $3 per gallon, the average new vehicle customer would only value a plug-in hybrid at about $1,000. Of course, this would change dramatically if fuel shortages were to occur. The government may also wish to explore ways to incentivize the full useful life savings to manufacturers or customers.

D. Environmental Considerations

From a societal point of view, there are additional issues with criteria pollutants and CO2 emissions. How the electricity is generated will have a significant impact on benefits other than energy security. If coal is the primary source of the energy, criteria pollutants and CO2 emissions will be higher with the plug-in hybrid. If renewable sources of energy are used to generate the electricity, plug-in hybrids can offer benefits for clean air and global warming. Another societal issue is end-of-life battery disposal. This is not likely to be a problem for NiMH batteries, as the raw materials are very valuable and recyclers will be active in setting up systems to recycle the batteries. However, it may be a problem for Lithium-ion batteries, where the raw materials are far less valuable. These are all additional areas for research.

E. Additional Research Is Needed

Honda strongly supports the research program outlined in the House discussion draft of the Plug-In Hybrid Electric Vehicle Act of 2006. Hybrids, including plug-in hybrids have a great deal of promise and their potential issues should be actively investigated for solutions, especially energy storage. The outlined research program is the best way for the federal government to accelerate the development and deployment of plug-in hybrid electric vehicles.

Fortunately, the Department of Energy is already developing plans to identify plug-in hybrid research needs and solutions. The Department of Energy held a Workshop on Plug-In Hybrid Electric Vehicles on May 4-5, 2006 to discuss issues and questions on plug-in hybrid research needs. The paper issued in advance of the workshop presented an excellent outline of the advantages of plug-in hybrids, the challenges faced, especially energy storage, the technical gaps, and the questions that need to be answered. The paper is an excellent resource for planning future research and development for plug-in hybrids and should be read by everyone interested in promoting plug-in hybrid vehicles. The Department of Energy's work in this area should be supported and funded by Congress.

I appreciate the opportunity to present Honda's views and would be happy to address any questions you may have.