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Chairman Biggert and Members of the Energy Subcommittee, thank you for the opportunity to testify today and share my thoughts on advanced automotive technologies. I will address the role that fuel cell vehicles and plug-in hybrids can play in reducing our nation's petroleum consumption and automotive emissions. I will discuss the major technical problems and research opportunities for each of these technologies, and provide an update on the recent progress that has been achieved.

Fuel Cell Vehicles

Let me start my testimony by recalling the benefits that fuel cell powered vehicles can provide to our nation. Fuel cell vehicles offer the potential to provide operation on petroleum-free fuel, with a fuel economy significantly exceeding today's internal combustion engine vehicles, while emitting only water vapor at the tailpipe. The Department of Energy (DOE) estimates that, if hydrogen reaches its full potential, the Hydrogen Fuel Initiative and FreedomCAR program could reduce our oil demand by over 11 million barrels per day by 2040 – approximately the same amount of crude oil America imports today.

However, in order for fuel cell vehicles to achieve widespread market penetration, key technical problems must be solved Cost and durability are the major challenges to fuel cell commercialization. Size, weight, and thermal and water management are also key barriers. Under the FreedomCAR and Fuel Partnership, a model of public/private collaboration, the Department of Energy is working closely with its national laboratories, universities, and industry partners to overcome critical technical barriers to fuel cell commercialization. The research program continues to focus on materials, components, and enabling technologies that will contribute to the development of low-cost, reliable fuel cell systems.

For automotive fuel cells, the two greatest problems are the cost and durability of fuel cells. In addition, onboard hydrogen storage and a viable supporting infrastructure of hydrogen production and distribution will also have to be established, but these issues have been addressed by previous witnesses today.

In order to have widespread market penetration, the cost of fuel cells needs to be reduced from their current cost (about $3,000/kW in small volume fabrication) to a target cost of $30/kW (in mass production). Independent studies, conducted by industry for the Department of Energy, have analyzed the cost of automotive fuel cell systems, if manufactured at mass production levels of 500,000 units per year. The results show that the cost projections for mass-produced fuel cells have been reduced by more than 50% since 2002 (from $275/kW to $110/kW) under the Hydrogen Fuel Initiative. This cost reduction was the result of increased power density;

advancements in membrane materials; reductions in both membrane material cost and amount of membrane material required in the fuel cell; enhancement of specific activity of platinum catalysts; and innovative processes for depositing platinum alloys. Further work at Argonne National Laboratory (and elsewhere) is directed towards reducing or eliminating the platinum content in the fuel cells, which, if successful, would have a direct effect on reducing fuel cell costs. Similarly, other components of the fuel cell and system (e.g., polymer electrolytes, hydrogen storage) stand to achieve higher performance at lower cost by the development of new materials.

Similar gains have been made in operating life. An operating life of at least 5,000 hours is required for automotive applications. During the last four years, the durability of fuel cell systems has been extended from 1,000 hours or less, to greater than 2,000 hours under real-world cycling conditions. Much progress has been made, but additional research is needed. The key to enhancing longevity is to understand performance degradation and failure mechanisms so that materials or engineering solutions may be devised to overcome them. This is another line of research sponsored by DOE at Argonne and other research organizations.

Plug-In Hybrid Electric Vehicles

"Plug-in" hybrids (i.e., those that can be plugged in and recharged from the electric grid and which provide some driving range on battery power only) offer the potential to provide significant fuel savings benefits, particularly for commuter and local driving. Additional research and development is needed for cost-effective plug-in hydrids. Specifically, improved batteries and corresponding improvements to the electric drive systems (motors, power electronics, and electric controls) will be required. Needed battery improvements include reduced size and weight, greater durability and lifetime, and lower cost. Since 2002, however, the projected cost of a 25-kW battery system for hybrid vehicles, estimated for a mass production level of 100,000 battery systems per year, has dropped by more than 35%.

The plug-in hybrid vehicle is a demanding application for the on-board energy storage device (battery). Nickel metal hydride batteries are used in conventional hybrid vehicles today. However, lithium-ion batteries are the most promising technology for use in this application, due to their high energy density and high power density. It is only a matter of time before they replace nickel metal hydride batteries in conventional hybrid electric vehicles. For the same amount of stored energy and power, lithium-ion batteries will be about 2/3 the size of a comparable nickel metal-hydride battery. The current state-of-the-art lithium-ion batteries already possess suitable power, energy, weight, and volume for use in plug-in hybrids that could provide at least a 20-mile range capability on batteries only. The issues of ruggedness (e.g., ability to withstand overcharging and extreme temperatures), long lifetimes, and cost remain barriers for this technology.

Various tradeoffs can exist in battery technology. For example, batteries with thick electrodes tend to have high stored energy but low power capability. On the other hand, batteries with thin electrodes tend to have high power density but lower energy density. This allows the battery developer the flexibility to design a battery with high power for a hybrid vehicle application, or one with high energy (and therefore high range) for an electric vehicle, or some intermediate combination that may be required for a plug-in hybrid. Similar tradeoffs between cost and life are also sometimes possible. However, in order for a battery to be successful, it must meet all the application requirements simultaneously. This can only be achieved through the development of new materials, components, and enabling technologies.

There exist numerous opportunities for reducing cost, extending life, and further increasing the energy density of lithium-ion battery technology. Currently, there are worldwide R&D efforts focused on the development of advanced anode and cathode materials that are less expensive and inherently more stable than those used in current state-of-the-art lithium-ion batteries (and Argonne is one of the world leaders in this area, via its DOE-funded R&D programs). Several of these advanced electrode materials offer the promise for simultaneously extending electric range (via increased battery energy density), extending battery life (via enhanced stability of materials), and reducing battery costs via two mechanisms -- lower battery material costs and reduced complexity of the battery management and control system (due to use of these more inherently stable materials).

The issue of rapid recharge for plug-in hybrids is much more an infrastructure issue than it is a battery issue. With 220-volt, 20-ampere electrical service available in households, it will take more than 2 hours to charge a 10-kWh battery (the approximate size battery needed for a electric range of 20-40 miles). Even current state-of-the-art lithium-ion batteries are capable of accepting a one-hour recharge.

Conclusion

In my *opinion*, there is no single solution -- the future will include a mix of technologies that includes improved internal combustion engines, alternative fuels, hybrids, plug-in hydrids, electric vehicles, and fuel cell vehicles. A range of technologies that will be needed to make fuel cell vehicles viable are the subject of ongoing research. These include lightweight materials, advanced batteries, power electronics and electric motors. Considerable progress to overcoming the barriers associated with each of these advanced technologies has been achieved during the last four years. The rate of continued progress will certainly depend on future levels of public and private investment.

The vision of fuel cell vehicles and plug-in hybrids as a solution to foreign energy dependence, environmental pollution and greenhouse gas emission, is compelling. The challenges on the road to achieving this vision can be addressed with innovative high-risk/high-payoff research. Argonne National Laboratory, together with other national laboratories, has a number of significant programs that will contribute to these future automotive technologies. We are working with the DOE Offices of Science, Energy Efficiency and Renewable Energy, Fossil Energy, and Nuclear Energy to create useful processes for building a hydrogen economy. We at Argonne are excited at the prospect of helping our nation in its transition to environmentally friendly, domestically produced sources of power.

Thank you, and I will be happy to answer questions.