Invited Testimony for the U.S. Senate Committee on Finance
Prepared Statement of
Dr. Robert Farrington
Manager & Principal Researcher, Advanced Vehicle Systems Group
National Renewable Energy Laboratory
Golden, CO
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Mr. Chairman, thank you for this opportunity to discuss the next generation of alternative fuels and vehicles. I am Rob Farrington, the Principal Researcher and Manager of the Advanced Vehicle Systems Group at the National Renewable Energy Laboratory, in Golden, Colorado. NREL is the U.S. Department of Energy's primary laboratory for research and development of renewable energy and energy efficiency technologies. I am honored to be here, and to speak with you today.

The committee is to be commended for its interest in finding alternatives to, and reducing our nation's dependence on, imported petroleum. NREL is dedicated to helping our nation develop a full portfolio of renewable energy technologies that can meet our energy needs.

My testimony today will focus on opportunities for reducing fuel use for ground transportation. The range of viable options fall into several broad categories – lowering miles traveled in personal vehicles, using alternative fuels and increasing the fuel economy of vehicles. Each option provides benefits, but might incur increased initial costs and some degree of risk.

Consumers in the United States purchase about 16 million cars, light trucks, and SUVs annually, and we have a total fleet size of about 225 million vehicles today. Currently, it takes about 15 years to turn over the entire fleet. To put that in perspective, if we were to somehow provide all of the new vehicles built from today going forward with some dramatically new technology, a decade from now fully 40 percent of our nation's vehicles still would not have benefited from those improvements. The lesson is that the impact of any new technology will take significant time to evolve. Therefore, our first priority should be to institute desired changes quickly and deliberately, so their benefits can begin to have an impact.

Any discussion of reducing our use of imported petroleum should begin with consideration of ways we can reduce overall use of fuels. This would encompass reducing the miles traveled in personal vehicles, as well as more efficient transportation systems within the commercial sector. So, when we weigh the overall effect, the many disparate policies that deal with mass transit, carpooling, high occupancy vehicle lanes and other highway usage measures, and even biking and walking, should be seriously considered, for these efforts can and should make very significant contributions to overall energy efficiency.

Looking at technology-based solutions, the development of alternative fuels has great potential. The U.S. currently produces about 5 billion gallons of ethanol annually, and that figure is growing rapidly given the number of new plants under construction or planned. Most of the ethanol produced today is blended with gasoline to produce a 10% ethanol blend. There are some 6 million vehicles on the road that can use up to E85, the 85 percent ethanol blend, or about 2.5 percent of our total passenger vehicle fleet. So there is considerable opportunity to expand use of ethanol within the existing fleet, and we have recently seen a new emphasis among automakers to expand the number of new vehicles sold with E85, or flex-fuel, capabilities. Only about 1,100 U.S. service stations, or about one-half of one percent of the total 170,000 service stations, currently offer E85, though the rate of growth for new ethanol pumps has been expanding rapidly in recent months. It should be remembered that the miles per gallon for ethanol is approximately 26 percent less than that of gasoline. That fact suggests that ethanol costs would have to be roughly a fourth less than those of gasoline to be equal on a cost-per-mile basis. Considerable opportunities exist for biodiesel as well; most biodiesel blends are designed to be used with conventional diesel engines.

The incremental cost of making a conventional gasoline vehicle into a flex-fuel vehicle is estimated to be about $50 to $200 for each vehicle. Automakers have announced plans to double the number of flex fuel vehicles produced each year by 2010, and make half of all new vehicles flex-fuel capable by 2012. This suggests that – at least in these early stages – we are on track toward transitioning our vehicle fleet to take advantage of the projected growth of ethanol production, as we move beyond the corn feedstock, and move in a major way to produce cellulosic ethanol, as federal policies envision for the future.

Perhaps the biggest opportunity before us is to increase overall fuel efficiency for passenger vehicles and light trucks. There are a number of ways to go about this. One way is to increase miles per gallon is to reduce the mass of the vehicle. Lighter-weight materials can go a long way in that direction. What is needed are lightweight materials inexpensive enough to replace more typical steel components, so the final product does not increase substantially in cost. Reducing aerodynamic drag, through advanced vehicle design, and reducing rolling resistance, also offer some possibilities.

One area that deserves more attention is the potential to reduce fuel use by cutting the consumption of auxiliary loads. Air conditioning can account for 10 percent or more of a vehicle's fuel consumption – more in some climates – and there are a number of promising technologies that may have the potential to drastically reduce air conditioning fuel use, while maintaining a comfortable cabin for a driver and passengers. Auxiliary load reduction is particularly important as we move toward electric drive propulsion, since those loads further drain the battery and reduce the range of the vehicle. The U.S. Department of Energy created analytical and experimental capability at NREL to develop and evaluate technologies to reduce climate control loads in collaboration with automotive companies and their suppliers.

There are powertrain technologies as well that can boost the miles per gallon achieved. Some involve more efficient designs of engine and transmission systems, others turn off selected cylinders when their power is not needed. Clean diesel is an option that is employed in Europe and gaining interest in the United States, not only for commercial vehicles, but also for personal vehicles.

Hybrid-electric vehicles (HEVs) have in recent years gained public attention and momentum in the marketplace, spurred on, at least in part, by favorable tax treatment from federal and state government. Hybrid-electric vehicles can save 20 percent to 50 percent of fuel consumption of comparable conventional vehicles, particularly in city driving. Hybrid systems turn off the gasoline-fueled engine when idling, such as when coasting or at a stop, use batteries and electric motors for short accelerations, recharge their batteries by recovering the energy used in braking and use batteries for auxiliary loads.

Sales of HEVs continue to grow and accounted for about 1.5 percent of the 16 million light duty vehicles sold in 2006, and about .3 percent of our overall fleet. Although this currently represents a small fraction, to date, we estimate hybrid vehicles have saved 230 million gallons of fuel.

The growing acceptance of hybrid-electric vehicles has helped spawn interest in utilizing electricity for our transportation needs, through plug-in hybrid electric vehicle (PHEV) technology. By relying on grid-produced electricity, plug-in hybrids have the potential to eliminate gasoline use and thereby reduce reliance on imported petroleum, for a large portion of the daily trips undertaken by a large segment of the driving population. Since the average trip length is 4.5 miles, and half of all daily driving is under 30 miles, a plug-in hybrid vehicle that could run 30 miles or more on electricity alone could displace significant amounts of imported oil.

Longer term, if PHEVs were to grow to a substantial portion of the U.S. vehicle fleet, there could be additional benefits associated with this technology. While the grid would of course provide needed electricity to the plug-in fleet, it is possible that collectively, plug-in hybrids could in turn create a new energy storage system, putting power back onto the grid, providing grid-charging, grid voltage stabilization and emergency power generation for the broader population of utility customers when needed.

Overall greenhouse gas emissions could be reduced if renewable electricity sources are used to charge the PHEV batteries, offsetting the large carbon dioxide footprint of our predominantly coal-based electricity generation system. Further advantages could be gained if plug-in hybrids were designed to use ethanol or a substantial ethanol-gasoline blend, rather than conventional gasoline, as fuel for those trips that extend beyond that which could be driven using stored electricity alone.

Hybrid-electric cars and plug-in hybrid cars each have advantages and disadvantages. The electric motors in HEVs can be used in tandem with the gasoline engine, and thus can be sized appropriately smaller than that for plug-in hybrids. The electric motor in PHEVs is larger than that in HEVs because it must be able to handle accelerations without turning on the engine.

Once the electric range is reached in a PHEV, it then operates as an HEV. It is possible that PHEVs could be designed with smaller electric motors, where the engine would assist with acceleration and hill climbing. The cost for energy storage, motors and electronics thus could be lowered. One of the benefits of both HEVs and PHEVs is that consumers can purchase vehicles with comparable characteristics of conventional vehicles that they prefer (e.g., the Ford Escape and the Ford Escape Hybrid) with no sacrifice of capability, often with improved performance and a reduction in fuel use.

Tailpipe emissions may constitute one potential issue surrounding plug-in hybrids. That is because plug-in hybrids might run long periods on electricity alone, and correspondingly long periods between use of the internal combustion engine. That could lead to multiple "cold starts" and increased tailpipe emissions given current catalytic converter design. Research into methods for managing the temperature of emission control systems could mitigate these concerns.

Energy storage remains the most critical barrier in the commercialization of plug-in hybrids, as it has been historically in the evolution of electric-powered vehicles. It is important to note that the battery requirements for HEVs and PHEVs are fundamentally different. HEVs might be likened to sprinters – they need high power for short distances, primarily in acceleration. PHEVs are more like cross-country runners – they need extra power to summit the hills but also need sustained energy over the longer haul.

These differing needs conflict with the limitations of current battery technology. HEVs are able to maintain battery life by only using about 10 percent to 20 percent of the available battery capacity, never coming close to depleting the energy in the battery. Because they rely on electricity alone for substantial travel, PHEVs require a lot more energy storage. To minimize cost, weight and volume, about 80 percent of the battery's capacity would be cycled daily in a PHEV. Beyond these concerns about "deep discharges," PHEVs will have numerous shallow discharges as well. The resulting impact on battery behavior and lifespan is not yet known, and should be the subject of continued research and testing.

Lithium ion batteries constitute the most promising battery technology for plug-in hybrids today, though lithium ion technology still must surmount several potential issues before it can be broadly commercialized for vehicle use. These issues include the potential for heat buildup during and following charging, the demands posed by extreme hot and cold climates and long-term reliability.

While lithium ion batteries are the focus for PHEVs, any development to reduce cost and improve lifetime will also benefit HEVs. The early application of lithium ion batteries may actually be in HEVs. This constitutes both a learning opportunity and a pathway to broader deployment in PHEVs. Toyota has indicated that they will use lithium ion batteries in the next generation Prius due in 2008 or 2009.

Further research is required to understand how consumers will use these vehicles in order to size battery systems correctly. Each additional kilowatt of energy storage costs the same. But if batteries are infrequently used, then they will have minimal benefits, and a higher cost per mile. On the other hand, PHEVs offer flexibility – batteries could be added to increase range after purchase, to suit individual needs.

From a U.S. economic and technology-competitiveness standpoint, it is important to note that nearly all batteries for HEVs, currently of nickel-metal hydride technology, and much of the power electronics, are manufactured in Japan with growing capacity in China and South Korea. In order for U.S. manufacturing to be competitive, we need to develop a domestic supplier base for HEV and PHEV components.

There are two significant government-industry partnerships engaged in research and development of HEVs and PHEVs, as well as other important advanced automotive technologies: the FreedomCAR and Fuel Partnership for light vehicles and the 21st Century Truck Partnership for heavy vehicles. Researchers at NREL, other national laboratories and within industry have identified energy storage, power electronics and electric motors – the subsystem needed to control and distribute electrical energy around the vehicle -- as areas where additional research related to HEVs and PHEVs would provide significant benefits to the nation.

Hybrid electric powertrains also provide opportunities for the nation's approximately 18 million commercial vehicles. Urban commercial vehicles, such as postal vehicles, refuse haulers, utility vehicles and delivery vehicles experience significant stop-and-go driving. The rigors of these short-haul commercial vehicles are well-suited to systems that capture braking energy, assist the engine during frequent accelerations and turn off the engine during coasting and stops. Such systems could reduce fuel consumption by 30 percent or more.

However, each of these unique commercial vehicles present a differing set of demands, which in turn determine vehicle size, configuration and duty cycles. As a result, each type of vehicle is likely to have a different hybrid powertrain solution. For example, the duty cycle of a refuge hauler most often consists of a long drive to a neighborhood, followed by repeated short starts and stops, ending with a long drive to a municipal waste site. Rather than using batteries, this application might be ideal for ultracapacitors – devices with very high power to move such a heavy load over short distances – while the engine is used only to and from the municipal waste site.

Hybrid transit buses are being used today and have demonstrated an average 27 percent reduction in fuel use. Depending on climate, about 25 percent of the fuel for transit buses is used for heating and cooling passengers. School buses can double the fuel economy with hybridization, but at twice the $70,000 price of a conventional bus. Postal delivery vehicles could benefit significantly from plug-in operation where they might use the engine to reach a neighborhood and then an all-electric mode while making mailbox-to-mailbox stops.

On the other end of the heavy vehicle spectrum, long-haul trucks, which operate at fairly constant speeds, consume nearly 16 billion gallons of diesel fuel annually. The opportunities here reside in more efficient engines, reduced aerodynamic drag, low rolling resistance tires and the opportunity to use biofuels. One promising method of cutting fuel consumption and tailpipe emissions is to use batteries to provide heating and cooling, and electricity for lighting, entertainment and ancillary equipment, during mandatory driver rest periods. Most of those needs today are met through idling of the truck's main engine.

Many other commercial vehicles also idle for extended periods during the delivery of packages or collection of refuse, or simply to operate necessary equipment like fans, extension buckets, backhoes, etc. Altogether, idling of commercial vehicles is estimated to consume more than 2 billion gallons of fuel annually, with commensurate production of unwanted emissions. Some of these loads during idle could be provided by battery packs, such as from a plug-in hybrid.

There are some promising developments in the commercial vehicle arena. FedEx currently is creating a fleet of 100 hybrid delivery vans with an estimated 57 percent improvement in fuel economy and significantly reduced emissions. The Sprinter delivery vans produced by DaimlerChrysler can travel 20 miles on electricity alone.

It may be helpful to look at relative fuel savings as a way to sort out the technology opportunities for achieving greater fuel efficiency in the U.S. A vehicle driven 12,000 miles, getting 25 miles a gallon, consumes 480 gallons of gasoline annually. A similarly-sized HEV might cost about $3,000 more, and at 40 to 50 miles per gallon, save as much as 180 to 240 gallons a year, respectively. A PHEV, meanwhile, at 80-100 miles per gallon, might save 330 to 360 gallons a year and could cost about an additional $9,000 beyond that of a conventional vehicle, if it were mass produced. If we look at the resulting fuel savings versus cost equation, a hybrid-electric vehicle would save about twice as much fuel per dollar of incremental cost – at today's projected costs.

Most automotive consumers focus on vehicle purchase price and not on lifetime costs which would include operating and maintenance costs. Cost reductions are needed to increase the market acceptance of HEVs and eventually PHEVs. Fundamental research is required to significantly reduce costs for energy storage devices and power electronics that will not come solely from mass production.

There are, however, other benefits that can be attributed to plug-in hybrids. PHEVs would mostly rely on domestically-produced electricity. The cost of this electricity would be about half as much as gasoline, calculated on a per-mile basis. And while that electricity today would be produced by significant amounts of coal and natural gas, plug-in hybrids could, over the longer term, be powered by renewable and other environmentally beneficial resources as our grid generation systems are diversified. It is assumed that most plug-in hybrids would be charged at off-peak periods to take advantage of favorable rates. PHEVs also have the potential for zero emissions for most trips in a typical urban environment, and could transfer day-time urban emissions to more remote nighttime emissions when off-peak charging is used. PHEVs also require minimal change in existing infrastructure, because a PHEV with a 30-mile range could use 110 volts, commonly available in garages, to charge a vehicle overnight.

In summary, the opportunities we have before us to increase energy efficiency and use of alternative fuels, including domestically produced electricity, that will reduce our reliance on imported oil have tremendous potential. About 60 percent of the crude oil we use is imported, and crude oil costs equal 56 percent of the price of a gallon of gasoline. Given that, a 20 mile-per-gallon vehicle will use about 8400 gallons of gasoline over its 14-year life, and consume about $8,500 worth of imported crude oil. Thus, efforts to reduce imported fuel consumption clearly can provide significant benefits for the U.S. economy, as well as the environment.

My testimony today shows, I believe, that a single solution to our transportation fuel challenges does not exist. Differing options offer various benefits and tradeoffs, and therefore national policies should be structured accordingly.

Current biofuels like biodiesel and corn ethanol – and longer-term, cellulosic ethanol – can displace significant amounts of imported petroleum while providing attendant environmental and economic benefits. Deployment of existing fuel-saving technologies, coupled with development of even more fuel-efficient methods, can still go a long way toward making today's conventional internal combustion engines more efficient.

At the same time, hybrid-electric vehicles could provide one of the quickest technological paths toward reducing imported oil – particularly if developed to use biofuels. However, HEVs are limited to reducing our fuel consumption by 20 percent to 50 percent. Longer term, plug-in hybrid vehicles offer the promise of eliminating our dependence on foreign-produced petroleum, and provide a transition to an all-electric personal transportation system which could include hydrogen fuel cell vehicles (FCVs) and perhaps also plug-in FCVs.

As we take the necessary steps toward a future where advanced vehicle technologies play a larger role, we should do so understanding the corresponding need to create a U.S. manufacturing base for HEVs and PHEVs and their components. It would be less than productive to trade our dependence on imported petroleum for a dependence on imported batteries. The lack of domestic industries to produce advanced battery and power electronics could, longer term, pose a serious issue for U.S. competitiveness. The U.S. currently relies almost exclusively on Japanese-produced components in these fields with growing capacity in China and South Korea.

The overarching goal should be to achieve the greatest impact in displacing foreign oil imports, long-term, collectively and nationwide. Any such portfolio should be directed at advancing multiple new technologies and fuels, as there is no single solution to our nation's energy and transportation challenges.

Thank you.