ENDING OUR ADDICTION TO OIL: ARE ADVANCED VEHICLES AND FUELS THE ANSWER?

FIELD HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY

COMMITTEE ON SCIENCE

HOUSE OF REPRESENTATIVES

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ENDING OUR ADDICTION TO OIL: ARE ADVANCED VEHICLES AND FUELS THE ANSWER?

MONDAY, JUNE 5, 2006

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENERGY,
COMMITTEE ON SCIENCE,
Washington, DC.

The Subcommittee met, pursuant to call, at 10:00 a.m., in the Main Council Chambers, Naperville Municipal Center, 400 South Eagle Street, Naperville, Illinois 60566, Hon. Judy Biggert [Chairman of the Subcommittee] presiding.

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Ending our Addiction to Oil: Are Advanced Vehicles and Fuels the Answer?

Monday, June 5, 2006

10:00 AM – 12:00 PM
Naperville Municipal Center
Naperville, IL

Witness List

Dr. James F. Miller
Manager of the Electrochemical Technology Program at Argonne National Laboratory

Mr. Al Weverstad
Executive Director for Mobile Emissions and Fuel Efficiency at the General Motors Public Policy Center

Mr. Jerome Hinkle
Vice President, Policy and Government Affairs, National Hydrogen Association

Dr. Daniel Gibbs
President of the General Biomass Company

Mr. Deron Lovaas
Vehicles Campaign Director for the Natural Resources Defense Council

Mr. Philip G. Gott
Director for Automotive Custom Solutions at Global Insight

HEARING CHARTER

SUBCOMMITTEE ON ENERGY
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Ending Our Addiction to Oil: Are Advanced Vehicles and Fuels the Answer?

MONDAY, JUNE 5, 2006
10:00 A.M.–12:00 P.M.
NAPERVILLE MUNICIPAL CENTER
400 SOUTH EAGLE STREET
NAPERVILLE, IL 60540

1. Purpose

On June 5, 2006, the Subcommittee on Energy of the House Committee on Science will hold a field hearing titled *Ending Our Addiction to Oil: Are Advanced Vehicles and Fuels the Answer?* The hearing will examine progress made in the development of advanced on-board vehicle and fuel technologies for passenger vehicles that can increase fuel economy or reduce oil consumption through fuel substitution.

2. Witnesses

- **Dr. Daniel Gibbs** is President of the General Biomass Company in Evanston, IL. His research interests are in enzymes that digest cellulose, paper waste utilization and cellulosic ethanol production.
- **Mr. Philip G. Gott** is Director for Automotive Custom Solutions at Global Insight, a major economic and financial forecasting firm.
- **Mr. Deron Lovaas** is the Vehicles Campaign Director for the Natural Resources Defense Council.
- **Mr. Jerome Hinkle** is the Vice President for Policy and Government Affairs with the National Hydrogen Association.
- **Dr. James F. Miller** is Manager of the Electrochemical Technology Program at Argonne National Laboratory. He is an authority on energy storage and energy conversion technologies, with a particular expertise in fuel cells and batteries.
- **Mr. Al Weverstad** is the Executive Director for Mobile Emissions and Fuel Efficiency at the General Motors Public Policy Center. He began his engineering career in 1971 with General Motors' Pontiac Motor and Marine Engine Divisions.

3. Overarching Questions

The Committee hearing will address the following questions:

1. What progress has been made towards realizing the Hydrogen Economy since the 2002 field hearing?
2. What new vehicle technologies and fuel choices might be available in the near future that could increase U.S. energy independence?
3. What technical and economic obstacles might limit or block the availability in the marketplace of cars built with new technologies or using advanced fuels?
4. What should the Federal Government be doing (or not doing) through research and development spending and through the implementation of energy policies to encourage the commercialization of, and demand for new vehicle technologies and fuels?

4. Brief Overview

Currently, the U.S. consumes roughly 20 million barrels of oil daily. Of that, 40 percent is used to fuel cars and trucks at a cost to consumers of more than $250 billion per year. By 2020, oil consumption is forecast by the Energy Information Administration to grow by nearly 40 percent, and our dependence on imports is projected to rise to more than 60 percent. A 10 percent reduction in energy use from cars and light trucks (achieved by introducing an alternative fuel or improving fuel economy) would result in displacing nearly 750,000 barrels of oil per day. A similar percentage reduction in petroleum energy use from heavy-duty trucks and buses would displace around 200,000 and 10,000 barrels per day, respectively. Both the Federal Government and industry are funding programs designed to create affordable vehicles that would use less or no gasoline or petroleum-based diesel fuel, including programs on hydrogen-powered fuel cells, biofuels, and hybrid vehicle technologies.

The Federal Government will spend over $200 million in fiscal year (FY) 2006 on such research and development (R&D) programs.

One focus of federal programs to increase fuel economy, and part of the President's Advanced Energy Initiative announced this year, is R&D to advance hybrid vehicles. Hybrid vehicles, such as the Toyota Prius or the Ford Escape, use batteries and an electric motor, along with a gasoline engine, to improve vehicle performance and to reduce gasoline consumption, particularly in city driving conditions. Plug-in hybrid vehicles are a more advanced version of today's hybrid vehicles. Plug-in hybrid vehicles require larger batteries and the ability to charge those batteries overnight using an ordinary electric outlet. Such a change would shift a portion of the automotive energy demand from oil to the electricity grid. (Little electricity in the U.S. is generated using oil.) Additional R&D is needed to increase the reliability and durability of batteries, to significantly extend their lifetimes, and to reduce their size and weight.

Fuel substitution R&D focuses on two fuel types: hydrogen and biofuels. Hydrogen gas is considered by many experts to be a promising fuel in the long-term, particularly in the transportation sector. When used as a fuel, its only combustion byproduct is water vapor. If hydrogen can be produced economically from energy sources that do not release carbon dioxide into the atmosphere—from renewable sources such as wind power or solar power, from nuclear power, or possibly from coal with carbon sequestration—then the widespread use of hydrogen as a fuel could make a major contribution to reducing the greenhouse gas emissions. On-board hydrogen storage remains a major technical hurdle to the development of practical hydrogen-powered passenger vehicles.

Biofuels, such as ethanol and biodiesel, are made from plant material, and therefore can result in decreased greenhouse gas emissions, since the carbon dioxide emitted when biofuel is burned is mostly offset by the carbon dioxide absorbed during plant growth. Biofuel R&D is directed toward developing low-cost methods of industrial-scale production, which includes advanced biotechnology and bioengineering of both plants and microbes (to help break down the plants into usable materials).

On May 24, 2005, the House of Representatives passed H.R. 5427, the appropriations bill for FY 2007 that includes funding for these programs. In the bill:

- the overall Vehicle Technology sub-account received $173 million, a reduction of six percent from last year's level. Within this amount, Hybrid and Electric Propulsion, part of the President's Advanced Energy Initiative, received $50 million, up 14 percent from last year.
- the Hydrogen Technology sub-account received $196 million, an increase of 26 percent from last year's level; about 42 percent of this is directed to the FreedomCAR program for hydrogen vehicles.
- the Biomass Technology sub-account, part of the President's Advanced Energy Initiative received $150 million, a 65 percent increase, most of which is directed toward biofuel development.

Historically, both the Hydrogen sub-account and the Biomass sub-account have been heavily earmarked, with 27 percent of Hydrogen funding and 57 percent of biomass funding diverted to Congressionally directed projects in FY 2006.

5. Background

On June 24, 2002, the Energy Subcommittee of the House Committee on Science held a field hearing at Northern Illinois University in Naperville, IL titled *Fuel*

Cells: The Key to Energy Independence?[1] The hearing focused on developments in hydrogen fuel cell R&D and provided a broad overview of fuel cells for all applications, not just transportation. Witnesses at that hearing were unanimous in their assessment that current technical approaches to on-board storage of hydrogen gas require too large a volume to be practical in vehicles. Solving the storage problem was identified as one of the toughest technical hurdles for the use of hydrogen as a transportation fuel. Their assessment was echoed subsequently by expert reports from the American Physical Society and the National Academy of Sciences.

Since that 2002 field hearing, the Federal Government has focused more attention on the development of advanced vehicle and fuel technologies. In his 2003 State of the Union Address, President Bush announced a $1.2 billion Hydrogen Fuel Initiative to reverse America's growing dependence on foreign oil by developing the technology needed for commercially viable hydrogen-powered fuel cells. From fiscal 2004 to 2006, over $625 million has been allocated to hydrogen research in Department of Energy (DOE), over 40 percent of which was directed to the FreedomCAR vehicle program. The White House Office of Science and Technology Policy established the interagency Hydrogen Research and Development Task Force to coordinate the eight federal agencies that fund hydrogen-related research and development. The *Energy Policy Act of 2005* authorized a broad spectrum of research programs related to advanced on-board vehicle, hydrogen and liquid fuel technologies.

With the release of his FY 2007 budget request, the President announced his Advanced Energy Initiative. This initiative provides for a 22 percent increase in funding for clean energy technology research at DOE. Two major goals of the initiative are to reduce demand through greater use of technologies that improve efficiency, including plug-in hybrid technology; and to change the way Americans fuel their vehicles by expanding use of alternative fuels from domestically-produced biomass and by continuing development of fuel cells that use hydrogen from domestic feedstocks.

Hydrogen

The widespread adoption of hydrogen as a transportation fuel has the potential to reduce or eliminate air pollution generated by cars and trucks, but the source of the hydrogen is important. Hydrogen must be produced from hydrogen-bearing compounds, like water or natural gas, and that requires energy—and, unlike gasoline, more energy is always required to produce it than is recovered when hydrogen is burned or used in a fuel cell. Hydrogen has the potential to reduce America's dependence on foreign oil, but how much it would reduce dependence depends on what energy source would be used to generate hydrogen gas in the first place.

If hydrogen can be produced economically from energy sources that do not release carbon dioxide into the atmosphere—from renewable sources such as wind power or solar power, from nuclear power, or possibly from coal with carbon sequestration—then the widespread use of hydrogen as a fuel could make a major contribution to reducing the emission of greenhouse gases.

A fuel cell is a device for converting hydrogen and oxygen into electricity and water. Fuel cells have been used extensively for electrical power in space missions, including Apollo and Space Shuttle missions. In cars, the electricity would then be used to run electric motors to drive the wheels. Technological breakthroughs have reduced the cost and size of fuel cells, making them promising sources of power for automobiles, but fuel cells are still far too costly for everyday use.

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[1] The Science Committee and its Subcommittees have held numerous hearings on the use of hydrogen since the announcement of the FreedomCAR Initiative by then-Secretary of Energy Spencer Abraham on January 9, 2002. The FreedomCAR program was centered on fuel cell vehicles that use hydrogen as fuel. The Full Committee held the following hearings:

- February 7, 2002—Full Committee Hearing on *The Future of DOE's Automotive Research Programs*
- April 2, 2003—Full Committee Markup of H.R. 238, *Energy Research, Development, Demonstration, and Commercial Application Act of 2003*
- March 5, 2003—Full Committee Hearing on *The Path to a Hydrogen Economy*
- March 3, 2004—Full Committee Hearing on *Reviewing the Hydrogen Fuel and FreedomCAR Initiatives*

The Energy Subcommittee held the following hearings:

- June 26, 2002—Subcommittee on Energy Hearing on *FreedomCAR: Getting New Technology into the Marketplace*
- June 24, 2002—Subcommittee on Energy Field Hearing on *Fuel Cells and the Hydrogen Future*
- July 20, 2005—Joint Hearing—Subcommittee on Energy and Subcommittee on Research—*Fueling the Future: On the Road to the Hydrogen Economy*

Furthermore, there are research challenges with the fuel itself. To serve as automobile fuel, hydrogen must be stored on-board, but storing pure hydrogen at room temperature requires a large volume. Researchers are therefore working on developing complex fuels that can be stored compactly but can release pure hydrogen as needed. A final obstacle to widespread use is the need for new fueling infrastructure. To make hydrogen-fueled automobiles practical, hydrogen must be as easily available as gasoline, requiring a widespread network of hydrogen fuel stations.

Virtually all major foreign and domestic automakers have produced hydrogen-powered concept and demonstration vehicles. For example, General Motors has produced several fuel cell vehicle prototypes, including the Hy-wire, Sequel and AUTOnomy concept cars and the HydroGen3 minivan. The minivan is being used in demonstration fleets, but at a cost of more than $1 million per vehicle, these vehicles are far from ready for the market. There are fourteen hydrogen fueling stations in the U.S., including one that General Motors and Shell opened in Washington, D.C., as part of a joint demonstration program. There are nine hydrogen stations in California, which has allowed Honda to offer one of its fuel cell cars, the Honda FCX, to a family in Southern California to demonstrate its day-to-day use.

Biofuels

Rising oil prices in recent years have heightened interest in a variety of alternative sources of liquid fuels. At present, two biologically-derived fuel forms, ethanol and biodiesel, are used in the United States to supplement supplies of conventional gasoline and diesel. Although biofuel combustion releases carbon dioxide, growing the agricultural products to create ethanol consumes carbon dioxide. Both ethanol and biodiesel can be readily blended with conventional gasoline or diesel, respectively, although the fraction of either biofuel is limited by compatibility with some materials in the fuel system and engine, or by gelling of the fuel mixture at low temperatures.

Ethanol is a renewable fuel produced by fermenting sugars from biological products. Many different sources can provide the fermentation feedstock, such as trees and grasses and municipal solid waste, but in the United States, ethanol is now most commonly made from corn. Research is focused on developing feedstocks other than corn, particularly feedstocks that are not otherwise used for food. This requires the development of enzymes to digest what is otherwise waste plant material—stalks, leaves and husks—into fermentable sugars. Known as cellulosic ethanol, ethanol produced using both digestion and fermentation can use more parts of a plant and can expand the variety of economically viable feedstock for the production of ethanol. This would allow introduction of a wide variety of other feedstocks, including woody plants like willow and fast growing switchgrass. As with all ethanol, compatibility with the current fuel infrastructure is not perfect: transportation and energy content are two concerns. Ethanol's detractors argue that because ethanol can absorb water, it cannot be transported in gasoline pipelines, and use of carriers other than pipelines may complicate gasoline substitution on a national scale. Additionally, ethanol is lower in energy per gallon than gasoline, so consumer expectations about how far they can drive on a gallon of fuel need to be managed accordingly.

Ethanol, in use for years in the Midwest as a gasoline additive for improving octane levels, is now finding wider use by replacing an older octane-boosting additive found to contaminate drinking water. Ethanol can, however, serve as a primary ingredient in vehicle fuel. One blend of ethanol and gasoline is E85, 85 percent ethanol and 15 percent gasoline. Many automobile manufacturers produce Flex-Fuel Vehicles (FFVs) that can run on either E85 or ordinary gasoline, a capability that does not significantly add to vehicle price. General Motors, DaimlerChrysler, Ford, and Nissan all produce FFV cars and trucks. (Some analysts point out that most of these FFVs were produced by manufacturers because they get a credit against their corporate fuel economy requirements, rather than because of any consumer or market demand for the fuel flexibility option.)

Ethanol fuels are also in widespread use abroad. Brazil instituted a policy to encourage flexible fuel cars during the energy crisis of the 1970s, and between 1983 and 1988 more than 88 percent of cars sold annually were running on a blend of ethanol and gasoline. Flex-fuel car sales fell after withdrawal of the subsidy, but even today, fuel in Brazil has a minimum of 25 percent ethanol. Most ethanol in Brazil is produced from sugar cane, a much more efficient process than producing ethanol from corn, as is done in the United States.

Biodiesel is a renewable fuel that can be used in diesel engines, but is produced from vegetable oils and animal fats instead of petroleum. Using biodiesel instead of petroleum diesel reduces emissions of pollutants such as carbon monoxide, particulates, and sulfur. Biodiesel-petroleum diesel blends, with up to 20 percent biodiesel, can be used in nearly all diesel equipment. Higher biodiesel percentage blends may require specialized engines, delivery, and storage technology. Biodiesel is used in the fleets of many school districts, transit authorities, national parks, public utility companies, and garbage and recycling companies.

E85 and biodiesel fuel stations are scattered around the country. There are 637 E85 fuel stations in the U.S., with 102 in Illinois, and there are 362 biodiesel stations in the U.S., with 11 in Illinois. Compared to the more than 200,000 standard gasoline stations, these biofuels are still very difficult to find. The Alternative Fuels Data Center provides maps indicating the locations of fueling stations with advanced fuels.[2]

Plug-in Hybrids

Hybrid vehicles combine batteries and an electric motor, along with a gasoline engine, to improve vehicle performance and to reduce gasoline consumption. Conventional hybrid electric vehicles recharge their batteries by capturing the energy released during braking or through a generator attached to the combustion engine. These energy management techniques mean that these cars dissipate less of the energy contained in their fuel as waste heat. Nearly 200,000 hybrid passenger vehicles, such as the Toyota Prius or the Ford Escape, were sold in the U.S. from 2000 to 2004. Over 40 transit agencies in North America use hybrid buses. There are approximately 700 hybrid buses in regular service in North America, with another 400 planned deliveries through 2006.

Plug-in hybrid vehicles are a more advanced version of today's hybrid vehicles. They involve larger batteries and the ability to charge those batteries when parked using an ordinary electric outlet. Unlike today's hybrids, plug-in hybrids are able to drive for extended periods solely on battery power, thus moving some of the energy consumption from the gasoline tank to the electric grid (batteries are typically charged overnight) and moving some of the emissions from the tailpipe to the power plant (where, in theory, they are more easily controlled).

Because most Americans commute less than 40 miles a day, plug-in hybrids operable for 40 miles on an overnight charge from the electric grid could reduce U.S. gasoline consumption significantly. The potential for oil savings is related to how far a plug-in hybrid can travel solely on battery power. The electricity used to charge the batteries overnight would be generated from domestic sources (only three percent of the electricity used in the United States is generated from oil) and that electricity would primarily be consumed at night when demand is low.

President Bush, as part of his Advanced Energy Initiative, has established the goal of developing technology that would enable plug-in hybrids to travel up to 40 miles on battery power alone. Plug-in hybrids could benefit consumers because of their greater fuel economy and the relatively low cost of energy from the electric grid. Some proponents of plug-in hybrids claim that consumers will be able to recharge their batteries overnight at gasoline-equivalent cost of $1 per gallon.

While plug-in hybrid vehicles offer many advantages, high initial costs prevent widespread commercial application. Specialty conversion kits are available to upgrade an ordinary hybrid to a plug-in hybrid—although in very limited quantities and at high cost (about $10,000 per kit). Many component technologies, particularly the batteries, will need to achieve significant cost reductions and improvements in reliability before plug-in hybrids are truly attractive to consumers at mass-market scale. Car companies are reluctant to invest in these technologies without demonstrable consumer demand. R&D is needed to increase the reliability and durability of batteries, to significantly extend their lifetimes, and to reduce their size and weight.

Because batteries on board a plug-in hybrids are recharged by plugging the vehicle into an outlet, these vehicles do not need new types of fuel stations. The large batteries used in plug-in hybrids might also be used to provide power back to the electric power grid. A fleet of plug-in hybrids could offer regulatory services (keeping voltages steady, etc.) to a modernized grid. Advocates say that such vehicle-to-grid transmissions could benefit individual car owners by allowing them to sell the use of their energy storage capacity to grid operators.

The development and widespread use of plug-in hybrid vehicles could act as a stepping stone toward hydrogen-based transportation and fuel cell vehicles, because the electric motors and power control technologies that are required for plug-in hybrid cars would also be useful in fuel cell vehicles.

The first plug-in hybrid produced by a major automaker, the DaimlerChrysler Sprinter van, has been delivered to U.S. customers for test purposes. Many other plug-in hybrids are being tested in prototype form by small firms and individuals.

[2] See *http://www.eere.energy.gov/afdc.*

6. Witness Questions

Dr. Daniel Gibbs

1. How widely available is ethanol today, and how many cars can use it?
2. What are the obstacles to expanding the variety of feedstocks available for conversion to ethanol? Are these hurdles mainly market failures and other economic barriers or are they technical in nature?
3. What is the largest technical hurdle for each of the following fuels: Corn ethanol, biodiesel, cellulosic ethanol? Does the current federal research agenda adequately address these technical barriers? What actions would most rapidly overcome these technical barriers?
4. Some advocates suggest that biofuels should substitute for 25 percent or more of the Nation's transportation fuel use. Are there market or other barriers that policy might overcome to accelerate realization of the 25 percent biofuels goal?

Mr. Philip Gott and Mr. Deron Lovaas

1. The auto industry in recent years has generally used technological improvements to increase performance instead of fuel efficiency. What would be required to lead automakers to apply technology advancements to improving fuel economy?
2. What hurdles must hybrids, flex-fuel, and hydrogen-powered vehicles clear before the automobile industry, industry analysts, and the automotive press accept these technologies and consumers buy them? How more or less likely is it that these radically new technologies—fuel cells, electric drive trains, or significant battery storage capabilities, for example—will be incorporated into cars rather than incremental innovations to internal combustion engines?

Mr. Jerome Hinkle

1. Many experts indicate that on-board hydrogen storage is the major bottleneck facing realization of the hydrogen economy. What research paths look the most promising for solving the on-board storage problem?
2. What technical barriers in the production and distribution need to be overcome to permit hydrogen to fuel a quarter of the cars on the highway?
3. What are the tradeoffs between centralized and distributed hydrogen production for fueling the transportation infrastructure?

Dr. James Miller

1. What are the two most significant technical obstacles to making hydrogen-powered fuel cell vehicles affordable and practical to use? What are those obstacles for plug-in hybrids? How soon is significant progress likely to be made on removing each of the obstacles you mention? Can either hydrogen fuel cell vehicles or plug-in hybrids advance rapidly enough to be a more practical alternative to reducing energy consumption and pollution than making continuing improvements in the internal combustion engine would be?
2. Batteries need to be more durable, more rapidly chargeable, have longer lifetimes, and reduced size and weight if plug-in hybrids are to become practical. How are those traits related to one another and are there trade-offs between these performance parameters? Which are the easiest to address? Which of these contribute most significantly to cost?

Mr. Al Weverstad

1. What are the significant cost and technical differences between a flex-fuel engine and a conventional engine? Are there specific challenges to incorporating flex-fuel technologies in plug-in hybrid electric vehicles? Why aren't these technologies incorporated in every car sold?
2. What technologies would automakers adopt first to enable passenger vehicle to have a fuel economy significantly higher than available today, say 60 miles per gallon? What technologies would be used to hit a 45 mile per gallon target? What technologies would be used to hit a 35 mile per gallon target?

3. Are there gaps in the government's advanced vehicles and fuels research and development portfolio that could help with the more rapid adoption of new technologies? Do the Department of Energy programs have the correct balance between research and technology demonstration?

Chairwoman BIGGERT. Good morning.

I would like to call this meeting to order. Welcome to today's hearing entitled *"Ending Our Addiction to Oil: Are Advanced Vehciles and Fuels the Answer?"*

I would now recognize myself for an opening statement.

I want to welcome everyone here to this Energy Subcommittee hearing. Today we're going to examine how new technologies and advanced fuels for passenger vehicles could help our nation's addiction to oil.

I want to thank my Ranking Member Mr. Honda for traveling here from his home in the Silicon Valley of California. I greatly appreciate the time he has taken to come to my favorite part of Illinois.

I also want to welcome my fellow Member of the Illinois Delegation and the Science Committee, Mr. Lipinski, and thank him for joining us today. He didn't have to come quite so far.

I also want to thank our host, Mayor Pradel, and the citizens of Naperville for opening their Municipal Center for us today.

Finally, I hope you all got a chance to look at the advanced vehicles parked outside, many of which run on alternative fuels. And that's why I'm afraid we started a little bit late because I got involved in driving a scooter and sitting in all the cars. So if you didn't have a chance to do that, they will still be out there after this hearing is over.

We wouldn't be able to peek under the hood or kick the tires of these hybrid, plug-in hybrid and flex-fuel vehicles today if it weren't for the good people at General Motors, Argonne National Laboratory, the Illinois Institute of Technology and Northern Illinois University. So, we thank them very much.

Transportation is always a major issue for suburban communities whether they are in my District, Mr. Honda's or Mr. Lipinski's. As a matter of fact, it was better roads, inexpensive vehicles and cheap gasoline that allowed these suburbs to flourish.

We see that transportation and oil are becoming increasingly important to the growing populations in China and India as well. In addition, various studies suggest that we have reached the peak of production, or will very soon, meaning the gap between supply and demand will only grow larger. This will give countries with sizeable oil resources, many of which are hostile to the United States, and their cartels even more opportunities to manipulate the global market for oil.

The bad news is that this confluence of factors already is hitting the pocketbooks of American families with oil and gas at more than $70 per gallon. The good news—oh, I'm sorry. Per barrel. Thank goodness it's not gallon yet.

The good news is that there's nothing like a $3 a gallon of gasoline to get everyone thinking about new and creative ways to make transportation more affordable, less polluting and less susceptible to the verges of the world oil market. More than anything else Americans just want to be able to hop into their cars and go. Very few care what makes their car go, they just want it to be inexpensive and easy to get.

Our interest today is in retaining that convenience and minimizing the cost to our national security, to our economic security and to our environment, not to mention to the family budget through the use of research and technology. We need to work towards cars that can run on whatever energy source is available at the lowest cost be it electricity, gasoline, biofuel, hydrogen or some combination of these.

In addition, we need to find ways to make these diverse fuels readily available across the country.

It is clear that both technical and market obstacles remain to realizing the potential benefits of all of the advanced vehicle technologies or alternative fuels that we will be discussing. What are the technical or cost competitiveness issues related to the important components such as batteries, fuel cells or power electronics? What are major hurdles that stand in the way of the production or distribution of advanced biofuels? What technology challenges have not received sufficient attention? Or, are the hurdles not technical? Do consumer preferences or auto industry inertia present the highest hurdles? What about the infrastructure costs?

I want to give the city Naperville credit for focusing on the demand side of this equation. As a founding member of the Plug-In Partnership Campaign, Naperville is one of 132 public power utilities in 43 cities, counties and local governments that have made soft purchase orders indicating a strong interest in buying flexible fuel, plug-in hybrid vehicles if they are manufactured. In one of these vehicles the average American who drives between 25 and 30 miles a day could complete his or her commute and run some errands without burning a drop of gasoline. That's good for energy security , not to mention the pocketbook.

As I see it, one of the most significant potential benefits of the plug-in hybrid is that it does not require a whole new refueling infrastructure. You can just pull into your garage at the end of the day and fill her up by plugging your car into a regular 120 volt socket in the garage. Imagine the convenience of recharging your car just as you recharge your cell phone, Blackberry or laptop every evening by simply plugging it in. The next morning unplug and you're ready to go.

The city of Naperville realizes that the best way to hasten the arrival of plug-in hybrids was to commit to buying one. You can do the same thing simply by going to *wwww.pluginpartners.com,* click on "What you can do" tab and fill-in the plug-in partner's petition. Let the automakers know that you'd be willing to pay a few thousand dollars more up front to buy a vehicle that would be much cheaper to operate, cleaner and could run on domestically produced electricity.

We are looking to our witnesses today to help us identify the most significant technical and market obstacles facing the widespread availability of the advanced fuel—advanced vehicle technologies and alternative fuels that will make our cars less dependent on imported oil. We need your help in determining what steps the Federal Government can take to remove those barriers, whether it's through focused research or tax incentives. Your input at this hearing is greatly appreciated and we look forward to your expert advice.

But, first, I would like to recognize the Ranking Member Mr. Honda for his opening statement.

Mr. Honda.

[The prepared statement of Chairwoman Biggert follows:]

PREPARED STATEMENT OF CHAIRMAN JUDY BIGGERT

Good morning. I want to welcome everyone to this Energy Subcommittee hearing. Today we are going to examine how new technologies and advanced fuels for passenger vehicles could help end our nation's addiction to oil.

I want to thank my Ranking Member, Mr. Honda, for traveling here from his home in the Silicon Valley of California. I greatly appreciate the time he has taken to come visit my favorite part of Illinois. I also want to welcome my fellow member of the Illinois delegation, Dr. Lipinski, and thank him for joining us today.

I also want to thank our hosts, Mayor Pradel and the citizens of Naperville, for opening their Municipal Center to us today.

Finally, I hope you all got a chance to look at the advanced vehicles parked outside, many of which run on alternative fuels. If you didn't, not to worry; they will still be there after this hearing is over. We wouldn't be able to peek under the hood or kick the tires of these hybrid, plug-in hybrid, and flex fuel vehicles today if it weren't for the good people at General Motors, Argonne National Laboratory, the Illinois Institute of Technology, and Northern Illinois University.

Transportation is always a major issue for suburban communities, whether they are in my district, Mr. Honda's, or Mr. Lipinski's. As a matter of fact, it was better roads, inexpensive vehicles, and cheap gasoline that allowed the suburbs to flourish.

We see that transportation and oil are becoming increasingly important to the growing populations in China and India. In addition, various studies suggest that we have reached peak oil production, or will very soon, meaning the gap between supply and demand will only grow larger. This will give countries with sizable oil reserves, many of which are hostile to the United States, and their cartels even more opportunities to manipulate the global market for oil.

The bad news is that this confluence of factors already is hitting the pocketbooks of American families, with oil over $70 per barrel. The good news is that there is nothing like a $3 gallon of gasoline to get everyone thinking about new and creative ways to make transportation more affordable, less polluting, and less susceptible to the vagaries of the world oil market.

More than anything else, Americans want to be able to hop into their cars and go. Very few care what makes their car go. They just want it to be inexpensive and easy to get. Our interest today is in retaining that convenience and minimizing its cost—to our national security, to our economic security, and to our environment, not to mention to the family budget—through the use of research and technology.

We need to be working towards cars that can run on whatever energy source is available at the lowest cost: be it electricity, gasoline, biofuel, hydrogen, or some combination of these. In addition, we need to find ways to make these diverse fuels readily available across the country.

Plug-in hybrids or hydrogen-powered fuel cells would allow us to run our cars using renewable sources such as solar and wind, other clean and abundant sources like nuclear and even coal preferably from power plants employing advanced clean coal technologies that I hope will soon be the norm. Flex fuel vehicles running on renewable biofuels, such as ethanol and biodiesel made from all kinds of plant material—not just corn—can significantly decrease greenhouse gas emissions. And as demand for biofuels increases, we can simply grow more of the feedstock, whether that's corn, sugar cane, or switchgrass. And the benefit of these advanced vehicle technologies and alternative fuels will reduce our dependence upon imported sources of oil.

It is clear that both technical and market obstacles remain to realizing the potential benefits of all of the advanced vehicle technologies or alternative fuels we will be discussing. What are the technical or cost-competitiveness issues with important components, such as batteries fuel cells or power electronics? What major hurdles stand in the way of the production or distribution of advanced biofuels? What technical challenges have not received sufficient attention?

Or are the hurdles non-technical? Do consumer preferences or auto industry inertia present the highest hurdles? What about infrastructure costs?

I want to give the City of Naperville credit for focusing on this market or demand side of the equation. As a founding member of the Plug-In Partner Campaign, Naperville is one of 132 public power utilities and 43 cities, counties, and local governments that have made "soft" purchase orders indicating a strong interest in buying flexible fuel plug-in hybrid vehicles—if they are manufactured. In one of these vehicles, the average American, who drives between 25 and 30 miles a day, could complete his or her commute and run some errands without burning drop of gasoline. That's good for energy security, not to mention the pocketbook.

As I see it, one of the most significant potential benefits of the plug-in hybrid is that they do not require a whole new "refueling" infrastructure. To think that you could pull into your garage at the end of the day and "fill 'er up" just by plugging your car into a regular, 120-volt socket in the garage is very appealing. Imagine the convenience of recharging your car just as you recharge your cell phone, blackberry, or laptop every evening—by simply plugging it in. The next morning, unplug it and you are ready to go.

The City of Naperville realized that the best way to hasten the arrival of plug-in hybrids was to commit to buying one. You can do the same thing. Simply go to *www.pluginpartners.com,* click on the "What You Can Do" tab, and fill in the Plug-In Partners petition. Let the automakers know that you'd be willing to pay a few thousand more dollars to buy a vehicle that would be cheaper to operate, cleaner, and could run on domestically produced electricity.

We are looking to you, our witnesses here today, to help us identify the most significant technical and market obstacles facing the widespread availability of advanced vehicle technologies and alternative fuels that will make our cars less dependent upon imported oil. In addition, we need your help determining what steps the Federal Government can take to remove those barriers, whether it's through focused research or tax incentives.

Your input at this hearing is greatly appreciated and we look forward to your expert advice, but first I would like to recognize the Ranking Member, Mr. Honda, for his opening statement. Mr. Honda.

Mr. HONDA. Thank you, Madam Chair. And I'm very, very glad to be here in the great prairie State of Illinois. Having grown up in the south side and north side Chicago, I feel close to home.

And this podium is beautiful. So the city really ought to be very proud of their facility. But this bench up here makes me feel like I'm in a sushi bar. So if anybody wants to, you can just step right up.

So I want to also thank all the witnesses for being here today to testify, and to all of you who have come here to hear more about this very important subject.

I'm especially glad that we've got a panel that can talk about a wide range of vehicle and fuel options for the future. Because I suspect it is going to take some combination of a number of different approaches to truly end our addiction to oil. We will probably need to use different solutions at different points of time, and we will probably want to use multiple technologies at the same time depending on the application. And what do I mean by that? Well, I have a hybrid, a Toyota Prius. I recently had the opportunity also to drive a Honda hydrogen fuel cell car. And while I wasn't able to participate, there was a plug-in hybrid test drive near the Capitol. These are three different technologies at different states of commercial readiness. One is here today, the hybrid; one will be available fairly soon, the plug-in hybrid as our Chairperson said, and some really would say that it's ready to go and all you have to do is put the money, and; one still requires the development of technology and infrastructure to be viable.

At different points in time different technologies will make the most sense economically. When you think about applications, passenger car use in the city is very different than freight hauling over long distances. Different technologies are likely to prove most appropriate for the different uses, and so a single solution probably isn't the best way to go.

That can be a good thing. Even if a traditional hybrid in use today gets bumped aside by plug-in hybrids for urban passenger use, we will still be able to use hybrids for other purposes.

Back in Washington we have had a few hearings over the last couple of years about particular aspects of this subject. Plug-in hybrids, prizes for development of hydrogen technology, hydrogen and the progress that is being made in addressing technical barriers to the use of hydrogen in vehicles, but because of the time constraints we have to work with there, we aren't able to get a broad group of people together in this time.

I'm glad that today we'll get to hear about many different technologies all in one hearing and we will have the opportunity to compare them to each other and see where they compliment each other. I know that in many cases there's still much basic R&D that needs to be done to overcome technical barriers, and I certainly want to hear about those so we can learn where we need to focus our efforts on the Subcommittee. And the barriers are both economical and technical. And perhaps if you have the will, you might want to also share with us some of the political barriers you may see in the development of these kinds of technologies.

But I also hope that we will hear about the value of demonstration projects which can serve to help identify some of the very technical barriers that an increased emphasis on research will aim to overcome. I fear that we might miss more obstacles until after we have made significant investments and time and resources if we stop working on demonstration projects. Back in my own District we are fortunate to have some projects such as the Santa Clara Valley Transportation Authority's Zero Emission Bus program and the use of natural gas vehicles at the Norm Mineta San Jose Airport, that have helped to demonstrate the feasibility of alternative fuel vehicles.

Chairman Biggert, thank you for putting together an interesting and technologically diverse panel from whom I look forward to learning a lot today.

I yield back.

[The prepared statement of Mr. Honda follows:]

PREPARED STATEMENT OF REPRESENTATIVE MICHAEL M. HONDA

I'm glad to be here in the Prairie State today, and I thank Chairwoman Judy Biggert for inviting me to participate in this hearing.

Thanks to all of the witnesses for being here to testify and to all of you who have come to hear more about this very important subject.

I'm especially glad that we've got a panel that can talk about a wide range of vehicle and fuel options for the future, because I suspect it is going to take some combination of a number of different approaches to truly end our addiction to oil.

We will probably need to use different solutions at different points in time, and we will probably want to use multiple technologies at the same time depending on the application.

What do I mean? Well, I have a hybrid Toyota Prius, I recently had the opportunity to drive a Honda hydrogen fuel cell car, and while I wasn't able to participate, there was a plug-in hybrid test drive near the Capitol.

These are three different technologies at different states of commercial readiness—one is here today (hybrid), one will be available fairly soon (plug-in hybrid, some would say it is here today!) and one still requires the development of technology and infrastructure to be viable. At different points in time, different technologies will make the most sense economically.

When you think about applications, passenger car use in the city is very different from freight hauling over long distances. Different technologies are likely to prove most appropriate for the different uses, and so a single solution probably isn't the best way to go.

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I know that in many cases there is still much basic R&D that needs to be done to overcome technical barriers, and I certainly want to hear about those so we can learn where we need to focus our efforts on the Subcommittee.

But I also hope that we will hear about the value of demonstration projects, which can serve to help to identify some of the very technical barriers that an increased emphasis on research would aim to overcome. I fear that we might miss more obstacles until after we have made significant investments of time and resources if we stop working on demonstration projects.

Back in my own district, we are fortunate to have some projects, such as the Santa Clara Valley Transportation Authority' Zero Emission Bus program and the use of natural gas vehicles at the Norm Mineta San Jose Airport, that have helped to demonstrate the feasibility of alternative fuel vehicles.

Chairwoman Biggert, thank you for putting together an interesting and technologically diverse panel from whom I look forward to learning a lot today. I yield back the balance of my time.

Chairwoman BIGGERT. Thank you, Mr. Honda.

We don't normally have opening statements from the Members, but since this is a field hearing I will recognize Mr. Lipinski for three minutes.

Mr. LIPINSKI. Thank you, Chairwoman Biggert.

I appreciate the opportunity to speak here today, and I appreciate you putting this together. It's certainly a critical problem that we're facing right now. Not just with the high gas prices, but all the other problems that are caused by our current energy situation. And I appreciate the work that you've done in terms of helping us in terms of research and development, and especially your work with Argonne Lab here. So you've done a lot of important work in the energy area.

So right now we're all being effected by high energy prices. But as I said, it's not just our pocketbooks that are hit by our current energy paradigm. Also our national security is threatened and our environment and public health are also threatened by the current burning of fossil fuels which we use now to fuel our vehicles. We really need to develop a new energy model and find solutions here at home, solutions that will strengthen our national security, boost our economy, and help protect our environment.

Now there are may possible alternatives, you know, ranging from the short-term such as conservation and increasing efficiency to long-term approaches such as the use of hydrogen, bottled fuels and batteries as well as other ideas that we'll hear about from our witnesses today.

I'm especially interested as a former mechanical engineer to hear ideas and suggestions that our witnesses have today for where they think we should go, what they think the possibilities are.

Now some of these tools are already at use on our highways. I have a Ford Escape hybrid, which has served me very well, and this technology certainly has proven valuable. But it's not the solution to all of our problems. We really need to find and work, do the R&D on all these different areas.

One area that I'm particularly interested in is hydrogen, which has a great potential to provide much of our transportation energy needs and be environmentally friendly when the hydrogen is produced from renewable fuels.

I'm very pleased that a couple of weeks ago the House of Representatives passed legislation that I introduced along with Representative Bob Inglis to create the H–Prize. Now the *H–Prize Act of 2006* creates different prizes for different advances in the use of hydrogen as a fuel since there are problems with creation, storage, transportation; all these must be overcome so that we can use hydrogen as a fuel, we could put a hydrogen car in everyone's driveway.

I drove a hydrogen car a couple of weeks ago. It drove fantastic. The only problem is the price tag, it's about $1.5 million. It's a little too high right now. So we need to do more work to bring down the price of this, but it's available, it's possible. And as we saw the cars out front, these technologies are there. The problem is making them efficient enough so that we can use this to give everybody a vehicle such as these in order to wean ourselves off of oil, which we use right now to move our vehicles.

Americans over the years have consistently faced monumental challenges, consistently have overcome them. And we did this with air travel, space exploration, just to name a couple, and now we have to do this with energy. We need to use our greatest resource, which is our ingenuity and creativity, which is on display right now from our witnesses. So I look forward to hearing from our witnesses and hear the testimony today.

Thank you.

Chairwoman BIGGERT. Thank you, Mr. Lipinski.

I'd like now to introduce our witnesses.

If Members wish to submit further additions to their opening statements, your statements will be added to the record without objection.

First of all we have Dr. James Miller, who is the Manager of the Electrochemical Technology Program at Argonne National Laboratory, right here in the 13th District. Welcome.

Mr. Alan Weverstad, who is the Executive Director for Mobile Emissions and Fuel Efficiency at the General Motors Public Policy Center. Thank you for being here.

Mr. Jerome Hinkle, Vice President, Policy and Government Affairs, the National Hydrogen Association.

Dr. Daniel Gibbs, President of the General Biomass Company, which is located in Evanston.

Mr. Deron Lovaas, Vehicles Campaign Director for the Natural Resources Defense Council.

And then Mr. Philip G. Gott, Director for Automotive Custom Solutions at Global Insight.

Welcome all of you.

As our witnesses probably know, the spoken testimony is limited to five minutes. After each witness, Members will have—after all of the witnesses, Members will have five minutes each for questions.

And with that, we will begin with Dr. Miller. You're recognized for five minutes, or about.

STATEMENT OF DR. JAMES F. MILLER, MANAGER, ELECTROCHEMICAL TECHNOLOGY PROGRAM, ARGONNE NATIONAL LABORATORY

Mr. MILLER. Chairman Biggert and Members of the Energy Subcommittee. Thank you for the opportunity to testify today and share my thoughts on the role that fuel cell vehicles and plug-in hybrids can play in reducing our nation's petroleum consumption. Let me start my testimony by recalling the benefits that fuel cell 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 omitting only water vapor at the tailpipe. However, in order for fuel celled 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 management are also key barriers.

In order to have widespread market penetration, the cost of fuel cells needs to be reduced from their current cost, about $3,000 per kilowatt in small volume fabrication to a target cost of about $30 per kilowatt in mass production.

Independent studies have analyzed the cost of automotive fuel cell systems if manufactured in 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 a factor of 50 percent since 2002. Further work at Argonne National Laboratory is directed toward reducing or eliminating the platinum content in the fuel cells, which if successful would have a direct effect on further reducing fuel cell costs.

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 hour 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 mechanism so that new materials or engineering solutions may be devised to overcome them. This is another line of research at Argonne.

Let me now turn to plug-in hybrid vehicles. 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 hybrid vehicles.

For the same amount of stored energy and power, lithium-ion batteries will be about two-thirds the size of a comparable nickel metal hydride battery. The current state of the art lithium-ion battery already possesses suitable power, energy, weight and volume for use in plug-in hybrids that could provide at least a 20 miles range capability on batteries only. The issues of ruggedness, by that I mean ability to withstand overcharging and extreme temperatures as well as long lifetimes and cost, remain barriers for this technology.

There exists numerous opportunities for reducing cost, extending life and further increasing the energy density lithium-ion battery technology. Currently there are worldwide R&D efforts focused on the development of advanced electrode 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 leader in this area.

Several of the these advanced electrode materials offer the promise for: Simultaneously extending electric range through increased battery energy density; extending battery life through enhanced stability of materials, and; reducing battery cost via two mechanisms, lower battery materials cost and reduced complexity of the battery management and control system.

In 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 hybrids; 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 light weight materials, advanced batteries, power electronics and electric motors.

The vision of fuel cell vehicles and plug-in hybrids as solutions to foreign energy dependency, environmental pollution and greenhouse gas emissions is a compelling vision. We at Argonne are excited about the prospect of helping our nation in its transition to environmentally friendly, domestically produced sources of energy.

Thank you. And I will be happy to answer questions.

[The prepared statement of Dr. Miller follows:]

PREPARED STATEMENT OF JAMES F. MILLER

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, on-board 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 percent 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 hybrids. 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 percent.

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 two-thirds 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 two 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.

BIOGRAPHY FOR JAMES F. MILLER

Dr. James Miller is currently the Director of the Electrochemical Technology Program at the U.S. Department of Energy's Argonne National Laboratory. He has over 33 years of research experience in developing advanced batteries for electric and hybrid vehicles, hydrogen storage materials, and fuel cells for automotive applications and distributed power. He has served on numerous review panels for the National Research Council and for the Department of Energy. He was the recipient of the 1998 Department of Energy Fuel Cell Program Award. He holds a Ph.D. degree in Physics from the University of Illinois, and an MBA degree from the University of Chicago.

Chairwoman BIGGERT. Thank you, Dr. Miller.

Next we have Mr. Weverstad. You're recognized for five minutes.

STATEMENT OF ALAN R. WEVERSTAD, EXECUTIVE DIRECTOR, MOBILE EMISSIONS AND FUEL EFFICIENCY, GENERAL MOTORS PUBLIC POLICY CENTER

Mr. WEVERSTAD. Good morning. My name is Alan Weverstad and I'm Executive Director for the Environment and Energy Staff at the GM Public Policy Center.

I'm pleased to speak to you today regarding GM's plans for development and implementation of advanced technologies into our future vehicles. This plan includes near-term steps such as continuing to make improvements to today's internal combustion engines and transmissions with increased E85 flex-fuel availability.

Mid-term steps, which are beginning right now such as more affordable and flexible hybridization of vehicles and long-term steps such as fuel cell powered vehicles with hydrogen. The answer to today's energy issues are not simple, and we believe that all of these technology will play an important role in America's energy future.

GM is leading the effort on flex-fuel vehicles capable of running on gasoline or E85 ethanol. These vehicles offer a choice to consumers, a choice that has significant energy and economic benefits. Ethanol is renewable and in high concentration blends helps reduce greenhouse gas emissions. As E85 it helps reduce United States' dependency on petroleum, diversifies our sources of transportation fuel and reduces smog forming emissions. Ethanol usage provides great opportunities for the domestic agriculture industry and should help spur new job growth in other areas.

When gasoline prices spiked in the aftermath of the hurricanes that devastated the Gulf Coast, ethanol become more visible and GM recognized an opportunity to become part of this growing movement. Earlier this year General Motors launched a national advertising campaign to promote the benefits of this fuel and the fact that we have today vehicles capable of using E85. We followed up with the launch of our Live Green Go Yellow website to make this information even more widely available. Traffic to that website quickly rose to the millions as consumers wanted to know about E85, GM flex-fuel vehicles and station locations.

With nearly two million E85 capable vehicles already on the road at General Motors and a plan to offer 14 separate E85 capable models in 2007 we wanted to make sure our consumers knew when they were getting this flexible capability. So GM launched a labeling effort that included an external badge on the vehicle noting its flex-fuel capability and a yellow gas cap to remind customers that their vehicle is capable of running on E85.

We have also embarked on—upon several significant partnerships to increase the availability of the ethanol fueling infrastructure. We have partnered with ethanol producers, fuel suppliers, State governments and others in Michigan, Indiana, California, Illinois, Minnesota and Texas with more to come.

For the United States, the growth of the ethanol industry raises enormous potential for displacing gasoline consumption in the transportation sector. If all of the five to six million flex-fueled vehicles on the road by the end of this year were fueled using E85, the United States could offset the need for 3.6 billion—that's with a B, billion gallons of gasoline annually. And for the individual consumer regularly filling a 2007 Tahoe with E85 would displace the use of over 600 gallons of gasoline each year.

These are impressive numbers so we need to find ways to increase availability of E85 in the marketplace.

Although E85 technology is generally well known, it is not costless to the manufacturers. E85 flexible-fuel capable vehicle requires fuel system materials with improved corrosion resistance. The fuel system parts involve include the fuel tank, the fuel pump and the fuel level sender, on board diagnostic pressure sensors and fuel injectors. Both the fuel pump and the injectors must be sized for significantly higher flow rates to compensate for E85's lower energy density. The cylinder heads and valve materials within the engines need to be able to withstand E85's different chemical properties. And finally, the fuel system software and calibrations must be tailored to recognized E85 or gasoline and adjust the fueling and spark timing accordingly.

Effecting all of these changes across a range of vehicles will take time. Effecting all of these—especially for full line automakers like GM which have a variety of engines and fuel systems that will need to be modified. In some cases for low volume products the new—or the new direct injection technologies it may not be cost effective to add this technology, especially since ethanol will not be displacing gasoline across the board like unleaded gasoline did in replacing leaded gasoline.

On the hybrid technology front later this year we will introduce the 2007 Saturn View Green Line Hybrid powered by a new more affordable hybrid system with a fuel economy improvement of approximately 20 percent over the conventional engine. The Saturn View Green Line is expected to deliver an estimated 27 miles per gallon in the city and 32 miles per gallon on the highway, the best highway milage of any SUV. This new more affordable hybrid system is leading the way for GM to offer the all new two mode full hybrid Chevy Tahoe and GMC Yukon in 2007.

In addition, GM is evaluating the potential for and cost effectiveness of plug-in hybrid vehicles. Essential to make this technology a success are lower costs, lighter faster charging batteries that can be used to propel the vehicle in most local commuting and other trips of up 20 miles without needing to use the internal combustion engine. While extensive battery research is being done, we are still not at the point where this technology is ready for widespread implementation.

Looking to the long-term, General Motors has placed a very high priority on fuel cells and hydrogen as a power source and an energy carrier for automobiles. To accomplish this GM's fuel cell program is focused on lowering costs and increasing reliability of the fuel cell stack demonstrating the promise of technology through validation programs and collaborating with other parties on the infrastructure issues that need to be addressed. We have made significant progress in several of these areas, including fuel cell power density by a factor of seven while enhancing the efficiency and reducing the size of our fuel cell stack. It's now half the size it was before significantly increasing fuel cell durability, reliability, reliability and cold start capability developing a safe hydrogen storage system that approaches the range of today's vehicles and reducing costs through technology improvements and system simplification.

With respect to collaboration, we are working with key partners on virtually every aspect of fuel cell and infrastructure technology. The FeedomCAR and the California Fuel Cell Partnership, and the Fuel Cell Partnership managed through the United States Department of Energy has proven to be an important forum for developing these issues and challenges.

Clearly huge challenges remain. Reliability of fuel cell stacks and storage of the hydrogen on board the vehicle must be resolved to draw American consumers to these vehicles. And the fueling infrastructure must be available so that owners of these vehicles have no concerns about where to get the hydrogen.

In conclusion, there is no one single solution to the challenges we face. We are concentrating our energies on a number of different fronts and believe that many of these technologies will coexist in the marketplace. General Motors has a rational advance technology plan that goes from the near-term focused on alternative fuels like E85 ethanol to the long-term hydrogen powered fuel cells. We are executing that plan. All of these will help to simultaneously reduce United States' energy dependence, remove the automobile from the environmental debate and stimulate economic and jobs growth.

Thank you.

[The prepared statement of Mr. Weverstad follows:]

PREPARED STATEMENT OF ALAN R. WEVERSTAD

Good morning. My name is Alan Weverstad and I am Executive Director for Environment and Energy in the GM Public Policy Center. I am pleased to be able to speak to you today regarding GM's near- and longer-term plans for development and implementation of advanced technologies into our future vehicles.

GM has always been a leader in the development and use of technologies in vehicles. From the move away from hand-cranked starters—to the highly successful catalytic control technology for vehicle emissions—to efforts to produce an innovative electric vehicle in the 1990s, GM has been instrumental in the implementation of advanced technologies.

Today, we are continuing to focus on ways to advance vehicle fuel economy, safety and emissions. And GM is actively engaged in all of these activities. We have a plan to address both the needs of our customers and the critical public policy issues facing us. This plan includes near-term steps, such as continuing to make improvements to today's internal combustion engines and transmissions and increased E85 flex-fuel capability; mid-term steps, such as more affordable and flexible hybridization of vehicles; and long-term steps, such as fuel cells powered by hydrogen. The answer to today's energy issues is not simple, and we believe that all of these technologies will play an important role in America's energy future.

Today, I am here to speak about our work in these areas.

GM is leading the effort on flex-fueled vehicles capable of running on gasoline or E85 ethanol. These vehicles offer a choice to consumers—a choice that has significant energy and economic benefits. Ethanol is renewable and, in high concentration blends, helps reduce greenhouse gas emissions; as E85 it helps reduce U.S. dependence on petroleum, diversifies our sources of transportation fuel, and reduces smog-forming emissions. Ethanol usage provides great opportunities for the domestic agriculture industry and should help spur new job growth in other areas.

Until last fall there was limited interest in the development of ethanol as an alternative fuel. But when gasoline prices spiked in the aftermath of the hurricanes that devastated the Gulf Coast, ethanol became more visible and GM recognized an opportunity to become part of the solution. Earlier this year, General Motors launched a national advertising campaign, beginning with the very visible 2006 Super Bowl, hosted in our own home city of Detroit. After the Super Bowl, we continued through the 2006 Winter Olympics, including launching our "Live Green, Go Yellow" website. Traffic to that website quickly rose to the millions—as consumers wanted to know more about E85, GM flex-fuel vehicles and station locations.

But that was just the beginning. With nearly two million E85 capable vehicles already on the road and a plan to offer 14 separate E85 capable models in 2007, we wanted to make sure our customers knew when they were getting this flex-fuel capability. So, GM launched a labeling effort that included an external badge on the vehicle noting its flex-fuel capability and a yellow gas cap to remind customers that their vehicle is capable of running on E85.

We have also embarked upon several significant partnerships to increase the availability of the ethanol fueling infrastructure. Most recently, GM partnered with Meijer, CleanFuelUSA, the State of Michigan and the State of Indiana to work toward approximately forty new retail outlets. We have previously announced similar partnerships in California, Illinois, Minnesota and Texas—working with a variety of energy companies, State agencies, and distribution outlets.

For the U.S., the growth of the ethanol industry raises enormous potential for displacing gasoline consumption in the transportation sector. If all of the five million flex-fueled vehicles on the road today were fueled using E85, the U.S. could offset the need for 3.6 billion gallons of gasoline annually. And for the individual consumer, regularly filling a 2007 Chevrolet Tahoe with E85 would displace the use of over 600 gallons of gasoline each year. These are impressive numbers, so we need to find ways to increase availability of E85 in the marketplace.

Although E85 technology is generally well known, it is not costless to the manufacturers. Each E85 flex-fuel capable vehicle requires fuel system materials with improved corrosion resistance. The fuel system parts involved include the fuel tank, fuel pump, the fuel level sender, the on-board diagnostic pressure sensor and the fuel injectors. Both the fuel pump and the injectors must be sized for significantly higher flow rates to compensate for E85's lower energy density. The cylinder heads and valve materials within the engine need to be able to withstand E85's different chemical properties. And finally, the fuel system software and calibrations must be tailored to recognize E85 or gasoline and adjust the fueling and spark timing accordingly. Effecting all of these changes across a range of vehicles will take time—especially for full-line automakers like GM, which have a variety of engines and fuel systems that will need to be modified. In some cases—for low volume products or new direct injection technologies—it may well not be cost effective to add this technology—especially since ethanol will not be displacing gasoline across the board, like unleaded gasoline did in replacing leaded gasoline.

On the hybrid technology front, later this year, we will introduce the 2007 Saturn Vue Green Line Hybrid, the first GM vehicle powered by a new, more affordable hybrid system. With a fuel economy improvement of approximately 20 percent over the Vue's conventional engine, the Saturn Vue Green Line is expected to deliver an estimate 27 mpg in the city and 32 mpg on the highway, the best highway mileage of any SUV. This new, more affordable hybrid system reduces fuel consumption in five ways. First, the system shuts off the engine when the vehicle is stopped, to minimize idling. Second, the system restarts the engine promptly when the brake pedal is released. Third, fuel is shut-off early while the vehicle is decelerating. Fourth, vehicle kinetic energy is captured during deceleration (regenerative braking) to charge an advanced nickel metal hydride battery. And finally, the battery is charged when it is most efficient to do so. This new and more affordable hybrid technology is leading the way for GM to offer the all new two-mode full hybrid Chevy Tahoe and GMC Yukon in 2007.

In addition, GM is evaluating the potential for and cost effectiveness of plug-in hybrid electric vehicles (PIHEVs). Essential to make this technology a success are lower cost, lighter, faster charging batteries that can be used to propel the vehicle in most local commuting and other trips (up to 20 miles or more) without needing to use the internal combustion engine. While extensive battery research is being done, we are still not at the point where this technology is ready for widespread implementation From GM's prior work on pure electric vehicle technology (especially production of the EV1) and through the company's broad work in hybrid technology, GM sees several challenges automakers will need to overcome to get this technology into the market.

The first is the significant cost challenge that is already present with hybrid vehicles, but then is amplified with the addition of plug-in capability. The increase in battery size is the most significant contributor to this additional cost.

Secondly, the additional battery mass and volume present considerable technical challenges to the vehicle design. With the pressure today to reduce vehicle mass and packaging space already at a premium for hybrid vehicles, this is a challenge that requires significant advances in battery mass and volume to accommodate.

Thirdly, the PIHEV will require advances in battery technology, specifically the development of a battery that has long life with high charge/discharge capabilities needed to propel the vehicle during EV operation. Promising results have been seen with next generation lithium ion battery technology, but this still requires study to know that the full range of vehicle performance characteristics can still be met.

Looking to the long-term, General Motors has placed very high priority on fuel cells and hydrogen as the power source and energy carrier for automobiles. To accomplish this, GM's fuel cell program is focused on lowering cost and increasing reliability of the fuel cell stacks, demonstrating the promise of the technology through validation programs and collaborating with other parties on the infrastructure issues that need to be addressed. We have made significant progress in several of these areas:

- In the last six years, we have improved fuel cell power density by a factor of seven, while enhancing the efficiency and reducing the size of our fuel cell stack.
- We have significantly increased fuel cell durability, reliability, and cold start capability.
- We have developed safe hydrogen storage systems that approach the range of today's vehicles.
- We have made significant progress on cost reduction through technology improvements and system simplification.

With respect to collaboration, we are working with key partners on virtually every aspect of fuel cell and infrastructure technology. The FreedomCAR and Fuel Partnership, managed through the U.S. Department of Energy, has proven to be an important forum for addressing these issues and challenges.

Clearly huge challenges remain. Reliability of the fuel cell stacks and storage of the hydrogen on board the vehicle must be resolved to draw American consumers to these vehicles. And the fueling infrastructure must be available so that owners of these vehicles have no concerns about where to get the hydrogen.

In conclusion, there is no one single solution to the challenges we face. We are concentrating our energies on a number of different fronts, and believe that many of these technologies will coexist in the marketplace. General Motors has a rational advanced technology plan that goes from near-term, focused on alternative fuels like E85 ethanol, to the long-term hydrogen-powered fuel cells. We are executing that plan. All of these will help to simultaneously reduce U.S. energy dependence, remove the automobile from the environmental debate, and stimulate economic and jobs growth.

BIOGRAPHY FOR ALAN R. WEVERSTAD

ALAN R. WEVERSTAD, Executive Director Mobile Emissions and Fuel Efficiency, Public Policy Center, General Motors Corporation. Mr. Weverstad began his career in 1971 in the engineering area with Pontiac Motor Division where he worked as a design release & development engineer in the chassis and engine development sections. In 1985 he became a part of the Chevrolet-Pontiac-GM of Canada team where he was involved in the emission certification of 77 engine families. He then joined the Marine Engine Division and in 1991 moved to the Environmental Activities Staff and GM Research working on vehicle emissions issues. He is now the Executive Director of the Environment & Energy Staff of the Public Policy Center.

Mr. Weverstad is the immediate Past Chairman of the California Fuel Cell Partnership and Vice President of the Engine Manufacturers Association. He is also on the Board of Directors for the Electric Drive Transportation Association and on the Board of Advisors for UC Riverside and California H2 Highway.

Mr. Weverstad is a graduate of General Motors Institute and holds a Bachelor of Science degree in Engineering from Oakland University.

TRUTH-IN-TESTIMONY DISCLOSURE FORM

Committee on Science

Witness Disclosure Requirement - "Truth in Testimony"
Required by House Rule XI, Clause 2(g)

Your Name: Alan R. Weverstad

1. Are you testifying on behalf of a Federal, State, or Local Government entity?
   Yes No

2. Are you testifying on behalf of an entity other than a Government entity?
   Yes No

3. Please list any federal grants or contracts (including subgrants or subcontracts) which you have received since (use October 1 of the prior two fiscal years, e.g. October 1, 2004):

   [NONE]

4. Other than yourself, please list what entity or entities you are representing:

   [General Motors Corporation]

5. If your answer to question number 2 is yes, please list any offices or elected positions held or briefly describe your representational capacity with the entities disclosed in question number 4:

   [Executive Director, Environment and Energy, Public Policy Center]

6. If your answer to question number 2 is yes, do any of the entities disclosed in question number 4 have parent organizations, subsidiaries, or partnerships to the entities for whom you are not representing?
   Yes No

7. If the answer to question number 2 is yes, please list any federal grants or contracts (including subgrants or subcontracts) which were received by the entities listed under question 4 since (insert October 1 of the prior two government fiscal years, e.g. October 1, 2004), which exceed 10% of the entities revenue in the year received, including the source and amount of each grant or contract to be listed:

[General Motors Corporation has annual revenue in excess of 180 billion dollars and the federal grants and contracts received by the Corporation do not exceed 10% of those revenues. However, GM does receive approximately 500-700 million dollars in annual revenue from the U.S. government. This revenue derives from a variety of sources -- contracts, cooperative agreements, grants and other agreements where GM is generally the prime contractor, a subcontractor or a subrecipient. The majority of this U.S. government revenue is through the sale of cars and trucks to federal government fleets through GSA, and from transmission sales and support for military vehicles by Allison Transmission. We also have assorted research, development, demonstration, test and evaluation programs with the U.S. Department of Energy, U.S. Department of Defense, and U.S. Department of Commerce.]

Signature:____________________________ Date:____________________

Chairwoman BIGGERT. Thank you very much.

Mr. Hinkle, you're recognized for five minutes.

STATEMENT OF JEROME HINKLE, VICE PRESIDENT, POLICY AND GOVERNMENT AFFAIRS, THE NATIONAL HYDROGEN ASSOCIATION

Mr. HINKLE. Chairman Biggert, Ranking Member Honda and Representative Lipinski and guests, good morning. The National Hydrogen Association welcomes the opportunity to discuss progress toward building the hydrogen economy. We would like to focus on those technical and policy challenges that will be most important to transforming our energy systems. Under your leadership, the Energy Subcommittee continues to help guide our country's search for critical energy alternative. We hopes—excuse me. We hope today's hearing will provide some insight gain in several key areas.

I notice that I'm slightly to the left of GM here, so I need to pick up my act.

For 17 years, the National Hydrogen Association has promoted transition to a hydrogen economy. Its 103 members represent considerable diversity; large energy and automobile firms, utilities, equipment manufacturers, small businesses, transportation agencies, national laboratories, universities and research institutions. In partnership with the United States Government and each other, we are a key part of the wave front of technical and economic action on hydrogen in the United States and abroad.

Hydrogen is our nation's premier energy destination. We'll need an army of dedicated and talented people to solve all the technical and market-building challenges along the way. The stakes are high, and we've got a lot of tough homework to do.

I note here that the Energy Policy Act of 2005, which is an important document here that needs to be completely realized in the appropriations process, intends with the regard to the hydrogen title in particular, to accelerate the research, development and demonstration programs in DOE, make government a more durable partner in its industrial relationships, give permanent authorization to the hydrogen programs in DOE and broaden the Secretary of Energy's authorities and provide the Secretary more than triple the resources to accomplish this. It builds on the strong foundation of DOE's prior work on hydrogen and the President's Hydrogen Fuel Initiative.

Recently the House passed H.R. 5427 where they fully funded DOE's request for $246 million for these programs, but there's a policy lag in the hydrogen program. Less than half, 47.5 percent of the Energy Policy Act's authorized funding level of $518 million has been requested by DOE for fiscal year 2007. We don't want to see the many opportunities for enhancing DOE hydrogen technology programs slip away at a crucial time in their history. For FY 2008 we would urge their program managers, perhaps with the support of the Committee, to utilize a much higher share of their budget authority which grows from $517/518 million in FY '07 to $740 million in FY '08. These are all in the authorization levels.

Nearly 53 percent of this funding is for R&D, including basic science which also needs to be expanded beyond its—beyond its $50 million in the current energy and water appropriation.

Adequate on-board storage is widely agreed to be a fundamental necessity for a successful light duty vehicle. Much progress has been made in resolving many of those technical issues since the Committee's last field hearing in 2002. As Mr. Weverstad mentioned GM and then Ballard also have made great strides in improving costs and energy density. And there's a—there's a—in the handout there is a combined set of graphs from the Department of Energy that shows how some of this improvement has transpired.

And I just want to note that this work, there's still lots to do but their work continues at an urgent pace.

And benefits have come with more orderly program planning that identifies a wide range of alternative approaches. And improving the program management in DOE has led to manageable gains in storage performance. So you can see how important that is.

We see real progress in storage but believe that smart full use of the increased resources for fuel cell technologies, Section 805 of the Energy Bill, could definitely improve program performance. We urge DOE to request full funding for that in their FY 2008 budget.

A systems view of storage—it takes on a different personality in a whole vehicle context. It's important to remember that a modern gasoline fueled automobile only utilizes less than 1.5 percent of the fuel's energy to propel the vehicle's payload. This leaves a lot of room for improvement.

Extra mass is just ballast. With more intensive application of modern aerospace composite materials and high strength, lightweight steels and alloys, coupled to the new flexibility in vehicle design that fuel cells and electric drive subsystems offer, a much more efficient vehicle package can be designed.

GM in particular has—has worked on this and looked at the flexibility in purpose built composite vehicle design. And Section 808 of the Energy Policy Act, Systems Demonstrations, encourage combined—combined learning demonstrations with optimized advance composite vehicle design. We'd like to see DOE fund some of that activity.

And as Amory Lovins once remarked "Why waste a fuel cell on a primitive platform."

To storage and distribution. There are technical barriers in production and distribution that need to be overcome. With about 220 millions cars registered in the United States, and that number will grow and about 17 million sold per year, the National Academy of Science estimates that 25 percent of the fleet would be replaced within 12 years while GM sees about 20 years to replace the entire fleet with good superior products in the market. This makes it possible to evolve hydrogen supply infrastructure along with vehicle production. Shell and Ballard and GM, all in a Senate hearing on hydrogen R&D last summer, late last summer, concurred that we could see a manufacturable fuel cell vehicle by 2010–2012 that would be competitive with those cars then for sale. And GM, of course, has made it fairly plain what their targets are with regard to this in 2010.

We've got in the handout packet there's some slides from Shell Hydrogen that you might find interesting with regard to where hydrogen production is right now. On a satellite picture of the United States at night, for instance, overlaid by a 100 kilometer circle surrounding today's refinery production sites for hydrogen, this covers over 100 of these cities and in urban areas and which puts about 60 percent of the U.S. population today within a 100 kilometers of a major source of hydrogen. And these are the places where the introduction of hydrogen fuel cell vehicles would likely to be focused starting with fleets of municipal and commercial buses and delivery vehicles and then evolving to fleets of cars and light trucks and finally to consumers

And we don't want to ignore the rule of stationary and portable fuel cells, and leading these transitions to providing high quality supplemental and distributed power to businesses and municipalities, and the early establishment of hydrogen supply networks.

New job growth and retention of existing jobs during a transformation to a hydrogen economy is going to be important. We'll see altered refinery and utility operations in producing hydrogen. In addition, we'd likely see considerable expansion in renewable energy production both for electricity and biofuels in widely dispersed agricultural regions of the United States some distance from the urban demand centers.

Also much of the hydrogen in the early years will likely be produced from widely distributed sources using electricity off the existing grid or natural gas in the existing pipeline system. These distribution networks, this infrastructure is large, it's reliable and it reaches all urban areas. In some places as the Hydrogen Utility Group says for decades we brought electrons to every home and business in the United States, why not protons? Well, that's a little different technical challenge, but the operations of these—this infrastructure is well understood and key investments have already been made. The smoothest stage of the supply transition will be made in this way.

These are valuable and essential assets, but they will need to be adapted to new business models. Depending on the highly varied and unique regional mix of generating capacity, the relative production efficiencies and carbon footprint of the possible hydrogen fuel cycles will all be quite different. As has been said here and has been—and needs to be said often, no single production strategy will work for the United States and all feasible techniques and sources for making hydrogen will likely be needed.

Chairwoman BIGGERT. Mr. Hinkle, could you sum up?

Mr. HINKLE. Yes, ma'am.

Chairwoman BIGGERT. Thank you.

Mr. HINKLE. Well, we have in the written package a number of suggestions for public investments in this area. And as Dan Quayle once observed: "the future will be better tomorrow."

Thank you.

[The prepared statement of Mr. Hinkle follows:]

PREPARED STATEMENT OF JEROME HINKLE

Chairman Biggert, Ranking Member Honda, Representative Lipinski and guests, good morning. The National Hydrogen Association welcomes the opportunity to discuss progress toward building the Hydrogen Economy. We would like to focus on those technical and policy challenges that will be most important to transforming our energy systems. Under your leadership, the Science Committee continues to help guide our country's search for critical energy alternatives—we hope today's hearing will provide some insight gain in several key areas.

For 17 years, the National Hydrogen Association has promoted a transition to a hydrogen economy through its extensive work in codes and standards, education and outreach, and policy advocacy. Its 103 members represent considerable diversity: large energy and automobile firms, utilities, equipment manufacturers, small businesses, transportation agencies, national laboratories, universities and research institutions. In partnership with the U.S. Government and each other, we are the wave front of technical and economic action on hydrogen in the U.S. and abroad—these are the people and organizations that are making great progress along a broad technical front, and will have a key role in implementing these technologies (please see the attached slides about the NHA).

Hydrogen is our nation's premier energy destination. We'll need an army of dedicated and talented people to solve all the technical and market-building challenges along the way. The stakes are high, and we've got a lot of tough homework to do.

The Committee has requested our views in several areas. We will comment on some of the key technical and deployment issues, and relate these to important provisions of the *Energy Policy Act of 2005.*

Energy Policy Act of 2005 (P.L. 109–58) and Fiscal Year 2007, 2008 Budget Action

Many of the provisions in EPAct 05 originated in S. 665, the *Hydrogen and Fuel Cell Technology Act of 2005,* introduced on March 17, 2005. Written in concert with industry and the Senate's Hydrogen and Fuel Cell Caucus, it became the heart of the Hydrogen Title (VIII) in the Senate's Energy Bill, S. 10, and subsequently a substantial part of the hydrogen language negotiated in the Conference Committee. It was signed into law by the President on August 8, 2005. Significant sections of the Act's Vehicle and Fuels Title (VII) also deal with early market transition for hydrogen and fuel cells.

Section 802 of the Act establishes the purposes of the Hydrogen Title:

- Enable and promote comprehensive development, demonstration and commercialization in partnership with industry

- Make critical public investments that build links to industry and the research community
- Build a mature hydrogen economy that creates fuel diversity in the massive U.S. transportation sector
- Create, strengthen and protect a sustainable energy economy.

In Titles VII and VIII, the Act clearly intends to accelerate the research, development and demonstration programs in DOE, makes the government a more durable partner in its industry relationships, gives permanent authorization to the hydrogen programs in DOE, broadens the Secretary of Energy's authorities and provides more than triple the resources to accomplish this. It builds on the strong foundations of DOE's prior work on hydrogen and the President's Hydrogen Fuel Initiative, which has planned to devote $1.2 billion to this work from 2004 through 2008. The EPAct 05 authorizes $3.73 billion over Fiscal Years 2006 through 2011, and "such sums as are necessary" through 2020 (please see the attached slides about the EPAct 05).

The House recently passed H.R. 5427, the *Energy and Water Development Appropriations Act for Fiscal Year 2007.* It mirrors DOE's Budget Request for hydrogen—$246 million for those programs included in Titles VII and VIII (under the Energy Efficiency and Renewable Energy and Science offices of DOE).

RD&D activity in the Government is fueled by these public investments. The level of funding requested by DOE is on a path established by the Hydrogen Fuel Initiative in early 2003. Much has changed since—by February 2003, we had already seen energy prices beginning their rise—the average world oil price was about $28/barrel, but by the end of May 2006 that price was nearly $64/b. The President and Congress have anticipated the need to seriously search for transportation fuel alternatives, but there is a policy lag in the hydrogen program—less than half (47.5 percent—$246 million) of the EPAct 05's authorized funding level of $518 million has been requested by DOE for FY 2007.

Action We don't want to see the many opportunities for enhancing DOE hydrogen technology programs to slip away at a crucial time in their history. Built on program success, Congress has given the Secretary extensive authority in the EPAct 05 to enhance Section 8o8 demonstration programs, particularly with respect to learning demonstrations, broader vehicle/fuel supply systems (including community systems), and the ability to have results from demonstrations revise the direction of R&D projects. DOE is well into planning for the FY 2008 budget cycle—we would urge their program managers, with the support of the Committee, to utilize a much higher share of their budget authority, which grows from $517.5M in FY07 to $739.5M in FY08. Nearly 53 percent of this funding is for R&D, including basic science, which also needs to be expanded beyond its $50M in the current Energy and Water appropriation. There are also significant opportunities in Title VII (Vehicles and Fuels) to have federal and State agencies take a leadership role in purchasing stationary and portable fuel cells and hydrogen supply systems as early adopters. This could be coupled, for instance, with DOE's Clean Cities program to demonstrate real systems in the urban areas where the first commercial deployments of vehicle fleets is most likely.

Critical Technical and Economic Challenges

In its pacesetting report, *The Hydrogen Economy: Opportunities, Costs, Barriers and R&D Needs* (April 2004), the National Academy of Sciences summarized their four most fundamental technological and economic challenges:

- Develop and introduce cost-effective, durable, safe and environmentally desirable fuel cell systems and hydrogen storage systems
- Develop the infrastructure to provide hydrogen for the light duty vehicle user
- Reduce sharply the costs of hydrogen production from renewable energy sources, over a time frame of decades
- Capture and store the carbon dioxide byproduct of hydrogen production from coal.

Storage As the Committee has noted, adequate on-board storage is widely agreed to be a fundamental necessity for a successful light duty vehicle. Stationary storage can be just as important for the fueling stations supplying the vehicles. Much progress has been made on defining and resolving some of the storage issues since the Committee's last field hearing in 2002. Both on-board and stationary storage have seen considerable improvement, especially in concert with the industry/DOE Technology Validation program.

GM and Ballard, for instance, have greatly improved fuel cell power density—GM by a factor of seven in the last six years, while enhancing efficiency and durability and reducing the stack size. Ballard reduced the cost in four years by 80 percent to $103/kW, still about three times the DOE's 2010 goal of $30/kW to be competitive with current ICE powered cars, but on a path to achieve that goal. Durability increased ten-fold. Their work continues at an urgent pace.

DOE and Department of Defense work, the President's Hydrogen Fuel Initiative of February 2003, and its support by industry and the Congress—all have led to more orderly program planning that identifies a wide range of alternative approaches to the materials and methods that could be used to store hydrogen. Improving the program management has led to measurable gains in storage performance (a summary description of the progress for 2005 is available on DOE's web site, *www.hydrogen.energy.gov*—the *Annual Progress Report,* pp. 459–462; see, also *www.er.doe.gov* for the DOE Science program, which has considerable work underway on fundamental science with regard to hydrogen storage).

(Note: please see the attached slide from DOE comparing the relative performance of several storage methods: *Hydrogen Storage Technologies,* which shows storage capacity and costs.)

From the graphs, it is clear that by the end of 2005, volumetric capacity (volume storage effectiveness) and gravimetric capacity (storage by weight) do not yet match the goals DOE has set for 2010 and 2015. Neither has system cost reached the targets, but all the 2010 goals are being approached in steady fashion. Can progress toward these goals be reached more quickly? **We see real progress in storage, but believe that smart, full use of the increased resources for Fuel Cell Technologies (Sec. 805) included in the EPAct 05 could definitely improve program performance. We urge DOE to request full funding in their FY 2008 budget.**

Associated graphs show how the cost curve for proton exchange membrane fuel cells is dropping with steady research effort, and also how hydrogen cost goals for fuel cell vehicles relate to gasoline/electric hybrids and gasoline/internal combustion engines, taking into account their relative efficiencies.

Something missing from DOE's planning is direct combustion of hydrogen in advanced piston engines. This is a conscious program resources decision to focus on what they see as the highest payoff efforts. Two NHA members, BMW and Ford, have done considerable work with a variety of engines running on hydrogen. BMW plans to introduce a 7 Series with a V–12 bi-fuel engine, perhaps before the end of the year. It has remarkable emissions, and excellent performance. We would like to see DOE devote some funding to direct combustion, as it offers much earlier market introduction and a bridge to the hydrogen economy through the establishment of hydrogen supply stations for a wider variety of vehicles and collocated stationary fuel cells for electrical power.

A systems view Focusing on storage and achieving a 300 mile range as if they were separate from other vehicle design parameters may limit the search for solutions within a whole vehicle context. It is important to remember that a modern gasoline-fueled automobile only utilizes less than 1.5 percent of the fuel's energy to propel the vehicle's payload. This leaves considerable room for improvement.

Extra mass is just ballast. With more intensive application of modern aerospace composite materials and high strength, lightweight steels and alloys, coupled to the new flexibility in vehicle design that fuel cells and electric drive subsystems offer, a much more efficient vehicle package can be designed. Aircraft designers have been coping with these problems for a hundred years. A personal vehicle, however must be much cheaper and simpler.

There is a significant interaction between mass and the size of the fuel cell, the amount of hydrogen stored on board, and range. Although DOE has advanced materials, vehicles and manufacturing projects, it is unclear whether these have achieved a high level of integration. Hence Section 808 (b) of the EPAct 05, *Systems Demonstrations,* that specifically combine learning demonstrations with optimized advanced composite vehicle design. DOE already plans for second generation vehicles in their Technology Validation learning demonstrations. Again, this is a real opportunity for DOE to utilize some of their new authority and resources in advancing the art of whole vehicle design. General Motors, for instance, has built several vehicles that incorporate not only advanced hydrogen fuel cell electric drive systems, but totally different platforms. As Amory Lovins has remarked, "Why waste a fuel cell on a primitive platform?"

(Note: please see the attached charts from General Motors, which highlight what they see as the key goals and challenges.)

Of some note is the GM chart encouraging DOE to strengthen their hydrogen program, a "bold new approach." By simply ratcheting up Corporate Average Fuel Economy standards, and achieving this through the use of hybrids of various types we do save oil, but only delay solving the critical transportation fuel diversity/security problem. The conclusion here is that we already know enough about the potential of a hydrogen economy, and the stakes are so high that we need to focus on total solutions rather than partial ones.

Technical barriers in production and distribution—where will the H2 Economy get built?

The Committee is concerned about the technical barriers in production and distribution that would need to be overcome to permit hydrogen to fuel a quarter of the cars on the highway. With about 220 million cars registered in the U.S., and about 17 million sold per year, it would take several years after a competitive vehicle was available for 25 percent of the existing fleet to be replaced. Since many owners have more than one registered vehicle, and there are somewhat fewer drivers than the entire vehicle stock, significant operational oil savings would occur well before 25 percent replacement. The National Academy study "upper bound" market penetration case assumes that competitive fuel cell vehicles enter the market in 2015 as part of the mix of hybrids and conventional internal combustion engine (ICE) powered vehicles. They estimate that 25 percent of the fleet would be replaced within 12 years, or by 2027.

GM and others see that within 20 years the entire fleet could turn over with a superior group of products, which makes it possible to evolve hydrogen supply infrastructure along with vehicle production. In testimony before the Senate last July, GM, Shell and Ballard all concurred that we could see a manufacturable fuel cell vehicle by 2010–2012 that would be competitive with those cars then for sale. GM's urgent target is to validate a fuel cell propulsion system by 2010 that has the cost, durability and performance of a mass produced internal combustion system.

GM and others have estimated that an infrastructure for the first million vehicles could be created in the U.S. for $10–$15 billion, making hydrogen available within two miles for 70 percent of the U.S. population, and connecting the 100 largest U.S. cities with a fueling station every 25 miles. Others see broader deployment costing nearer $20 billion, not appreciably more than what the industry reportedly spends each year to simply maintain its current gasoline supply system.

Substantial oil savings would result when 25 percent of the fleet is replaced, resulting in lessening peak refinery capacity needs, as gasoline demand begins to shrink. Since much of the current industrial hydrogen production is utilized by oil refineries in making modern gasolines, some of this could now become merchant hydrogen supply. The attached Shell Hydrogen slides are suggestive.

The first of these shows a satellite picture of the U.S. at night, overlaid by 100 km circles surrounding today's refinery production sites for hydrogen. These are also the major urban, higher density gasoline demand areas—over 100 of them—meaning that at some 60 percent of the U.S. population is within 100 km of a major source of hydrogen today. And these are where the introduction of hydrogen fuel cell vehicles would likely be focused—starting with fleets of municipal and commercial buses and delivery vehicles, and then evolving to fleets of cars and light trucks, and finally to consumers. We would expect stationary and portable fuel cells to lead these transitions in providing high quality supplemental and distributed power to businesses and municipalities, and the early establishment of hydrogen supply networks.

Shell's next few slides discuss how a transition needs to be managed—in terms of key "Lighthouse" projects—those sized correctly and smart enough to provide a beacon to lead the way to something larger. A critical component is the quality of public/private partnerships—something the EPAct 05 stresses. The coordination of "Infrastructure Rollout" is a critical aspect—if it is uncoordinated, excess retail and manufacturing capacity outruns demand, leading to high costs for hydrogen that further dampen demand and shrink profitability. They see that an excellent match between the rates of demand and supply growth optimizes investment in capacity, and a more orderly and rapid transition. Lighthouse Projects are the harbingers of commercial success, and primary showcases for how well public and private institutions cooperate in establishing the climate for growth—whether it be in North America, Europe or Asia.

It is interesting to speculate on how the industrial base for a hydrogen economy might evolve. As a result of a study called for in Section 1821 of the EPAct 05, *Overall Employment in a Hydrogen Economy,* DOE will soon have underway an economic development analysis that looks at different transitions to varied forms of a hydrogen economy, to accompany other such work on market and technology transitions. It is expected that both new job growth and retention of existing jobs during a transformation like this would center on the supply chain for new vehicles, and much altered refinery and utility operations producing hydrogen. In addition, we would likely see considerable expansion in renewable energy production—both electricity and biofuels—in widely dispersed agricultural regions of the U.S. some distance from urban demand centers.

Also, much of the hydrogen in the early years will likely be produced from widely distributed sources, using electricity off the existing grid or natural gas from the existing pipeline system. These distribution networks are large, reliable and reach all urban areas. The combined electrical grid is connected everywhere—as the Hydrogen Utility Group suggests, "For decades, we have brought electrons to every home and business in the U.S.; why not protons?" Their operations are well understood, and key investments already made. The smoothest stage of the supply transition will be made in this way.

And since hydrogen does not lend itself to worldwide transport like oil and liquefied natural gas, it will not be as fungible internationally as oil—yielding domestic and regional markets where value can be based largely on market fundamentals and cost of production and transportation, unhooked from global volatility. This could also make the tools of government incentives—investment, production and use tax credits, loan guarantees, etc., more effective and predictable. Domestic production of hydrogen is the next wave of products for the energy industry, and promises considerable economic growth opportunities.

Depending upon how existing manufacturing capacity is converted and preserved in traditional areas, the automobile supply chain might have more inherent flexibility in locating new and old operations. The advanced fuel cell vehicle could have only one-tenth as many moving parts as today's cars, SUVs and pickups, and much of the rest of the vehicle would be different. Transformation would happen everywhere. True worldwide markets will evolve for components and vehicles, and manufacturing capacity is more mobile than hydrogen production.

Large export markets are expected to evolve for vehicles and components, and also for the technology surrounding hydrogen production and storage. Due to its particular appeal in improving the efficiency and shrinking the carbon footprint of conventional fuel cycles, hydrogen-related technologies will help create an even wider range of new export opportunities. International competition could be fierce.

Centralized and Distributed Hydrogen Production

As noted above, the U.S. has some of the basic infrastructure already in place that could be utilized in transitioning to a hydrogen economy—plants near oil refineries that manufacture hydrogen from natural gas and some byproduct plant fuel, and the nationwide electric power grid. These are valuable and essential assets, but they will need to be adapted to new business models. Depending upon the highly varied and unique regional mix of generating capacity (coal, hydroelectric, nuclear, renewable), and how effectively they can grow, the relative production efficiencies and carbon footprint of the possible hydrogen fuel cycles will be quite different.

No single production strategy will work for the U.S., and all feasible techniques and sources for making hydrogen will likely be needed—but more uniform emissions, costs and oil savings criteria can be applied. There may be an important new role for the Federal Energy Regulatory Commission (FERC), especially with regard to enabling rule-makings for producing more renewable electricity if a national Renewable Portfolio Standard were to be adopted (in the Senate's Energy Bill, but defeated in the EPAct 05 Conference). Investment decisions selecting between alternative sources of hydrogen could vary considerably, and the Committee needs to encourage R&D investment that can make these distinctions.

In shaping possible regulations for greenhouse gas management in the U.S., emission allowances and credit valuations could be designed to favor system design and technology deployment that minimize carbon emissions across the entire fuel cycle, not just for a particular energy sector. Proposals for investing in advanced low carbon technologies, funded by the sale and trade of carbon credits, might be structured to assist the most promising hydrogen supply and use technologies. The EPAct 05 Hydrogen and Incentives Titles are reasonably clear on the intent to select those public investments in technologies that optimize their carbon footprint. The carbon characteristics of particular projects funded through the Indian Energy Title are likewise important system performance criteria.

Action So, where does the key technical work need to be done, and what is government's role? The above discussion of the EPAct 05 advocates fuller funding in FY08 of all the key components of the Act with regard to hydrogen and fuel cells for vehicles. The Act attempts to reach forward to give DOE the authorities it needs to be more aggressive in creating more technical solutions more quickly. Besides making the vehicle and drive package lighter, cheaper and more efficient, the supply infrastructure needs equivalent attention, and new legislation might be needed to help.

- **Multiple sources of H2—**the U.S. has enormous coal reserves, but some reluctance to move quickly on solving its fundamental problems at an equivalent scale. The EPAct 05 has an excellent Coal Title, but little of it has been funded. There needs to be some agreement forged on the scale of public investment, including projects like that in Section 411, which is a regional 200 mW Integrated Gasification Combined Cycle (IGCC) facility that would make hydrogen and electricity, used in a power park setting. Many unused opportunities exist in Title XVII, *Incentives for Innovative Technologies,* (loan guarantees) which could be applied very fruitfully in combination with Title V, *Indian Energy* (which has its own loan guarantee program), and Title VIII, *Hydrogen.* We need to build flexibly sized, innovative commercial scale plants that match the pace of the hydrogen technology program's accomplishments with vehicles. Additionally, Title XVI, Subtitle A, *National Climate Change Technology Deployment,* could readily be combined with the Coal, Indian Energy, Incentives and Hydrogen Titles to put some key projects in place that would provide substantial learning and commercial possibilities.
- Although there is a uniform strategic plan for the climate program in DOE and other agencies, there are a very wide variety of projects across the government whose effectiveness in actually solving critical problems with coal, for instance, may be unlikely. It is unclear that the degree of fragmenting allows critical focus on solving key public problems, especially since they are located in so many separate agencies. A critical review and redeployment could be useful.
- Very useful R&D can be planned at the front end of a small commercial scale demonstration, encouraging an iterative R&D evolution much like the Learning Demonstrations are employed to revise R&D agendas in the H2 programs. Full scale tests of new materials and processes could speed eventual commercial deployment. We would include consideration of how Title VI, Subtitle C, *Next Generation Nuclear Plant Project,* could be enhanced.
- There are significant opportunities, for instance, for advanced ceramic materials to be used in higher temperature applications for carbon capture from advanced coal gasification processes, and in nuclear hydrogen production. *The American Competitiveness Initiative* in the DOE Science program has an advanced materials program that could contribute fundamental knowledge in these areas.
- DOE has been working to improve the efficiency and durability of electrolyzers, which are a critical component of early distributed generation strategies. More needs to be done in the area of materials, processes, manufacturing and validation.
- **Renewable H2—**again, less innovative use of the EPAct 05 authority shrinks our horizons. The public investment in wind, biomass and solar production of hydrogen needs to grow, both with regard to fundamental science and learning demonstrations. For those technologies that have true commercial appeal, the suite of authorities in the Incentives, Climate Change, Indian Energy, and Electricity Titles offer some intriguing possibilities for R&D focused on solving real public problems. More exploratory work in the DOE Science program could speed the availability of direct biological and solar hydrogen production, perhaps teamed in their advanced stages in Learning Demonstrations in specific regions and cities.
- **Electrical grid—**sizable renewable resources are often far away from urban load centers, but the Western Area Power Administration (WAPA) could be a key factor in bringing renewable electricity to high growth population centers in the Southwest and California. Significant planning studies have already been done on how to get more wind on the wires so renewable electricity from the Northern Great Plains—where the richest wind resources are—could be moved to high demand areas for hydrogen.
- Important work needs to be done on much more sophisticated control systems, composite materials and processes for enhancing transmission efficiency and high throughputs in corridors where there are significant siting problems. Much could be done to improve the potential for transmitting renewable energy to market.
- **Management organization—**The Committee is considering versions of an ARPA–E bill, based on the quick and flexible management often used in the Department of Defense by the Advanced Research Projects Agency, and placing such an organization within DOE. Working directly under the Secretary

of Energy, an ARPA–E would be able to identify promising technologies in an R&D stage, and nurture them through demonstrations and early market acceptance. They would have expedited personnel and procurement authorities, and be able to integrate all their necessary technical authorities into a single management structure. For instance, in the above examples of combining multiple authorities from the EPAct 05, it is unlikely that a traditional federal agency structure could accomplish blending the necessary functions, because they are often assigned to completely separate programs whose cooperation is incidental.

- Some have described the quest for a hydrogen economy as needing an Apollo or Manhattan Project's urgency—symbolic models for sustained high levels of funding and commitment to results. An ARPA–E for DOE could do that—placing all hydrogen and carbon reduction enabling work under single directorates, and holding them to high standards of performance until critical results are achieved.

We greatly appreciate the opportunity to contribute to a discussion that is critical to our collective future. The National Hydrogen Association looks forward to working with the Committee in shaping and achieving our common goals.

June 5, 2006

THE NATIONAL HYDROGEN ASSOCIATION

The Transition to Hydrogen

Jerome Hinkle
Vice President, Policy and Government Affairs

Who is the National Hydrogen Association?

[The Transition to Hydrogen] [2]

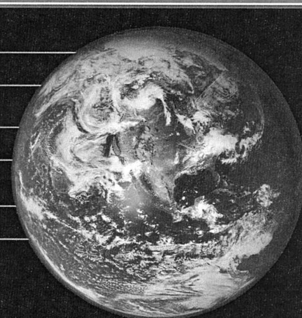
Who is the National Hydrogen Association?

- **Mission**
  - " Promoting the transition to hydrogen in the energy field."
- **Membership**
  - More than 100 companies and organizations (energy companies, auto manufacturers, small business, universities, laboratories, government and non-profit organizations)
- **Program Priorities**
  - **Safety, Codes & Standards** development
  - **Education & Outreach** to media, policymakers, safety and permitting officials, educators, students and the public
  - **Policy** advocacy and advising government leadership
- **Leading information resource** on hydrogen and hydrogen technologies

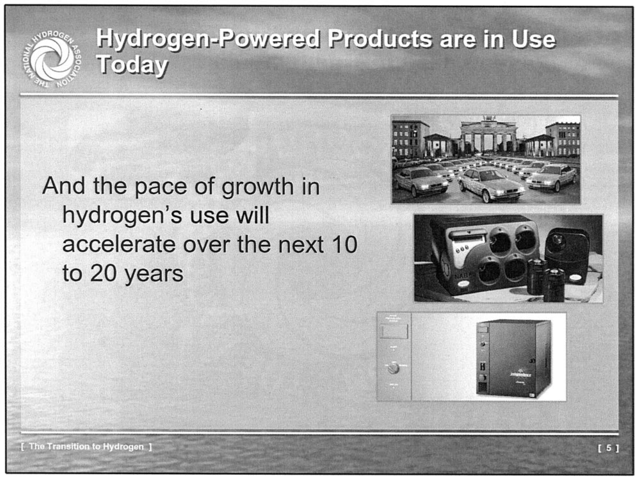
[The Transition to Hydrogen] [3]

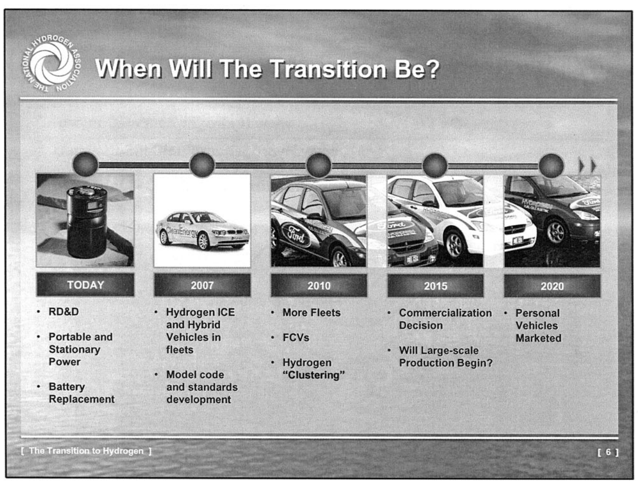
Increased Use of Hydrogen as a Fuel Provides Benefits to:

- ENERGY SECURITY
- THE ENVIRONMENT
- ECONOMIC GROWTH



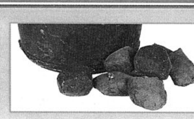
[The Transition to Hydrogen] [4]

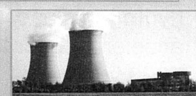

Hydrogen-Powered Products are in Use Today
And the pace of growth in hydrogen's use will accelerate over the next 10 to 20 years
[The Transition to Hydrogen]
[5]


When Will The Transition Be?
TODAY
• RD&D
• Portable and Stationary Power
• Battery Replacement
2007
• Hydrogen ICE and Hybrid Vehicles in fleets
• Model code and standards development
2010
• More Fleets
• FCVs
• Hydrogen "Clustering"
2015
• Commercialization Decision
• Will Large-scale Production Begin?
2020
• Personal Vehicles Marketed
[The Transition to Hydrogen]
[6]

Endpoint: A Diverse Portfolio Of Feedstocks and Technologies

- As much renewable energy as practical
- Coal with carbon sequestration
- Nuclear with issues resolved
- Natural gas plays key role in early years





[The Transition to Hydrogen] [7]

Where To Find the NHA

On the Web: www.HydrogenAssociation.org

www.HydrogenandFuelCellSafety.info

www.HydrogenandFuelCellJobs.com

www.HydrogenConference.org

UNITED STATES

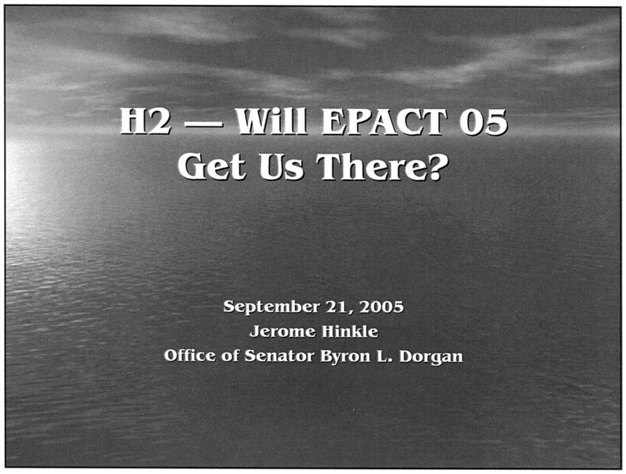
National Hydrogen Association
1800 M Street NW
Suite 300-North
Washington, DC 20036
ph: 1.202.223.5547

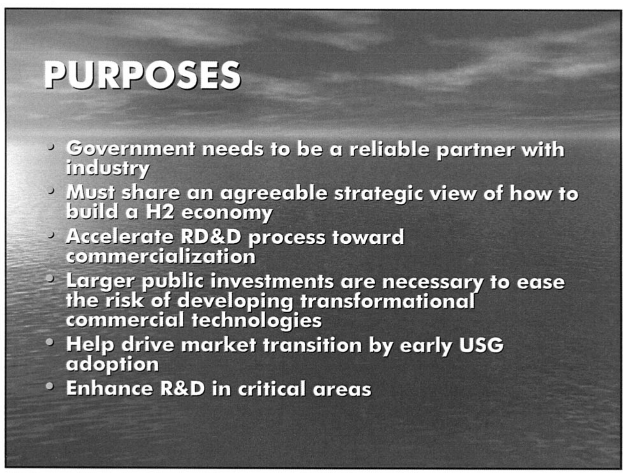
Western Region Office
35 Seascape Drive
Sausalito, CA 95965
Ph: 415.381.7234

EUROPE

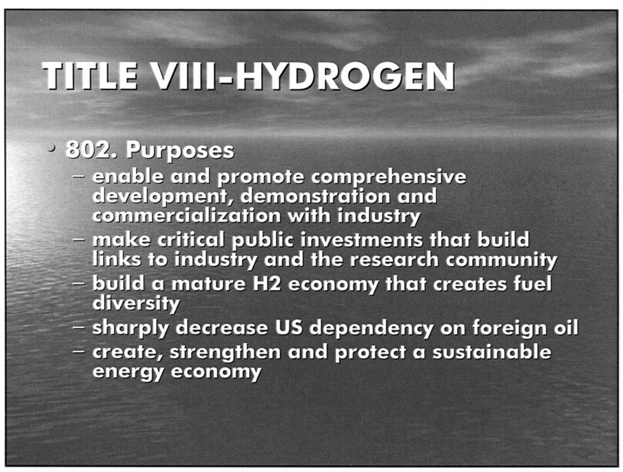
Gateshead International
Business Centre
Mulgrave Terrace
Gateshead, Tyne & Wear
NE8 1AN, United Kingdom
ph: 44.0.191.490.9440

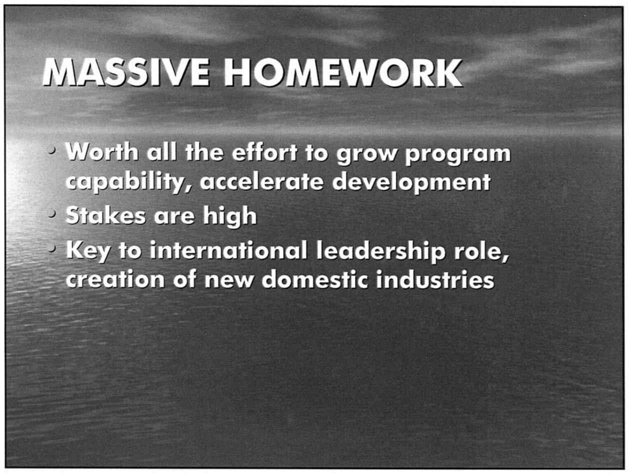
[The Transition to Hydrogen] [8]

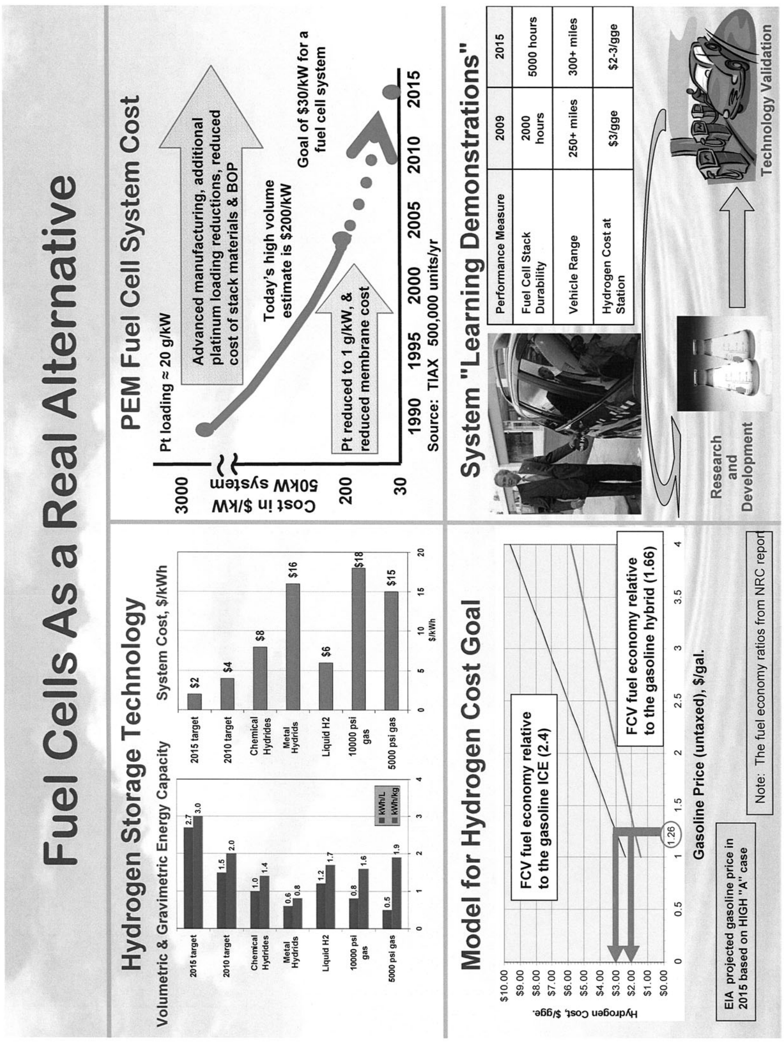

H2 — Will EPACT 05
Get Us There?
September 21, 2005
Jerome Hinkle
Office of Senator Byron L. Dorgan


PURPOSES
Government needs to be a reliable partner with industry
Must share an agreeable strategic view of how to build a H2 economy
Accelerate RD&D process toward commercialization
Larger public investments are necessary to ease the risk of developing transformational commercial technologies
Help drive market transition by early USG adoption
Enhance R&D in critical areas

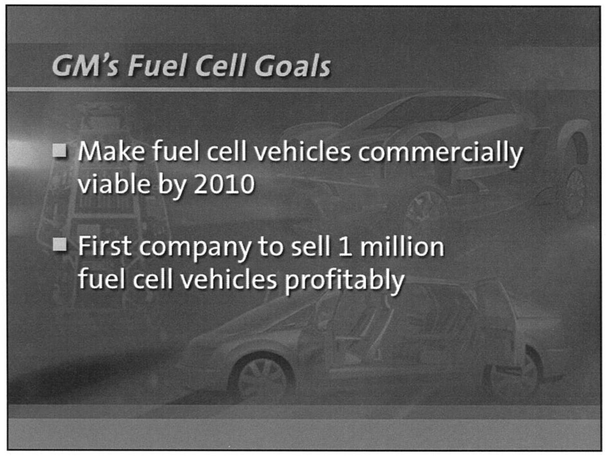

PURPOSES
• Link USG more closely with industry
• Expand learning demonstrations
• Build on DoE's progress with the H2 Initiative
– better tools to achieve key long range goals
– a permanently authorized program
– reshape programs to create more quality technical solutions more quickly

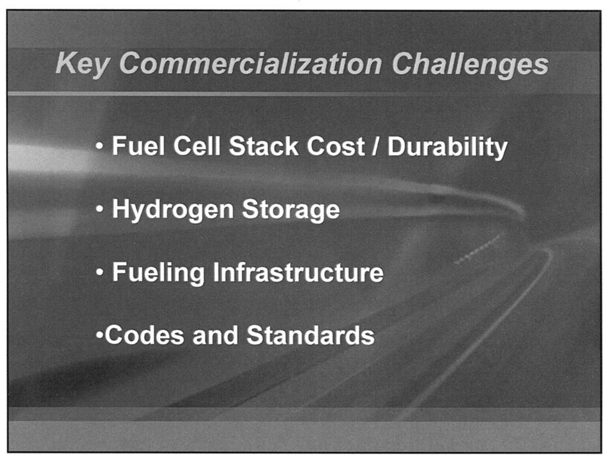

TITLE VIII-HYDROGEN
• 802. Purposes
– enable and promote comprehensive development, demonstration and commercialization with industry
– make critical public investments that build links to industry and the research community
– build a mature H2 economy that creates fuel diversity
– sharply decrease US dependency on foreign oil
– create, strengthen and protect a sustainable energy economy


MASSIVE HOMEWORK
• Worth all the effort to grow program capability, accelerate development
• Stakes are high
• Key to international leadership role, creation of new domestic industries

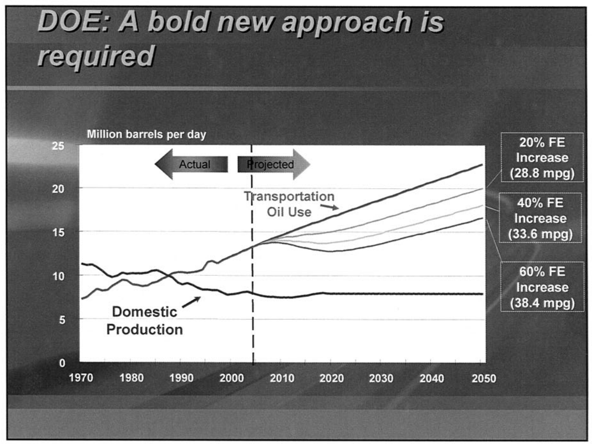

Fuel Cells As a Real Alternative
Hydrogen Storage Technology
Volumetric & Gravimetric Energy Capacity
System Cost, $/kWh
2015 target
2010 target
Chemical Hydrides
Metal Hydrids
Liquid H2
10000 psi gas
5000 psi gas
kWh/L
kWh/kg
$/kWh
PEM Fuel Cell System Cost
Cost in $/kW 50kW system
Pt loading ≈ 20 g/kW
Advanced manufacturing, additional platinum loading reductions, reduced cost of stack materials & BOP
Today's high volume estimate is $200/kW
Goal of $30/kW for a fuel cell system
Pt reduced to 1 g/kW, & reduced membrane cost
Source: TIAX 500,000 units/yr
Model for Hydrogen Cost Goal
Hydrogen Cost, $/gge.
FCV fuel economy relative to the gasoline ICE (2.4)
FCV fuel economy relative to the gasoline hybrid (1.66)
Gasoline Price (untaxed), $/gal.
EIA projected gasoline price in 2015 based on HIGH "A" case
Note: The fuel economy ratios from NRC report
System "Learning Demonstrations"
Performance Measure | 2009 | 2015
Fuel Cell Stack Durability | 2000 hours | 5000 hours
Vehicle Range | 250+ miles | 300+ miles
Hydrogen Cost at Station | $3/gge | $2-3/gge
Research and Development
Technology Validation

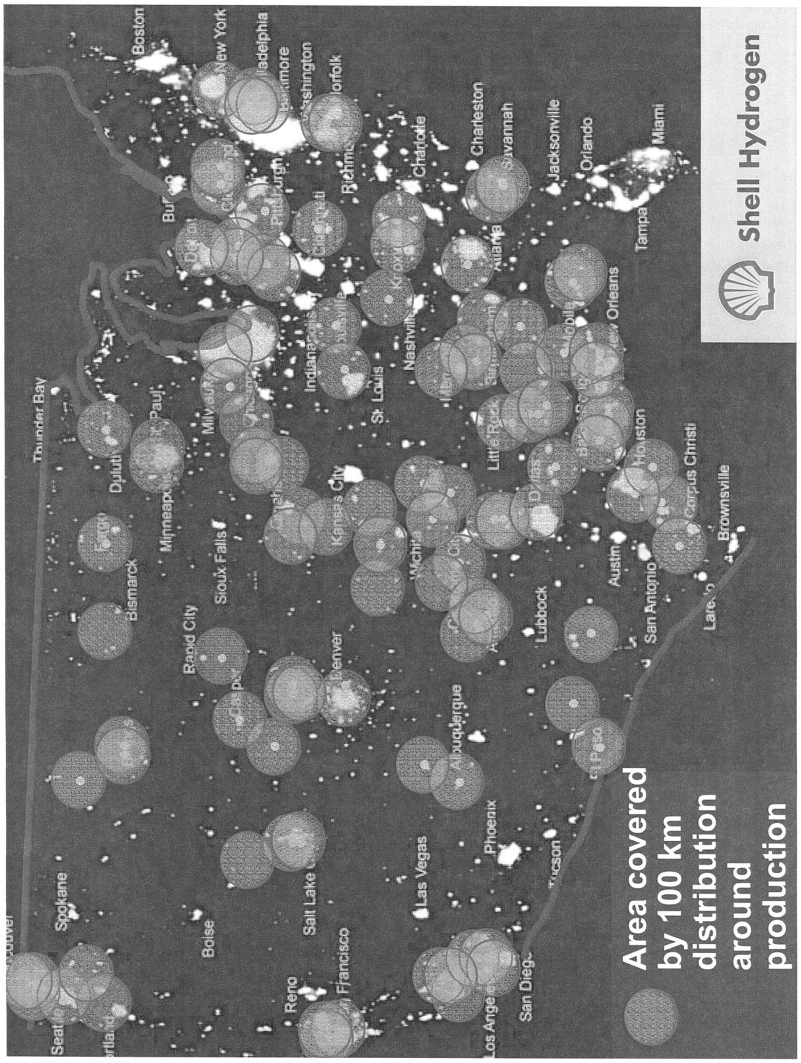
2003 Q2 Broadcast

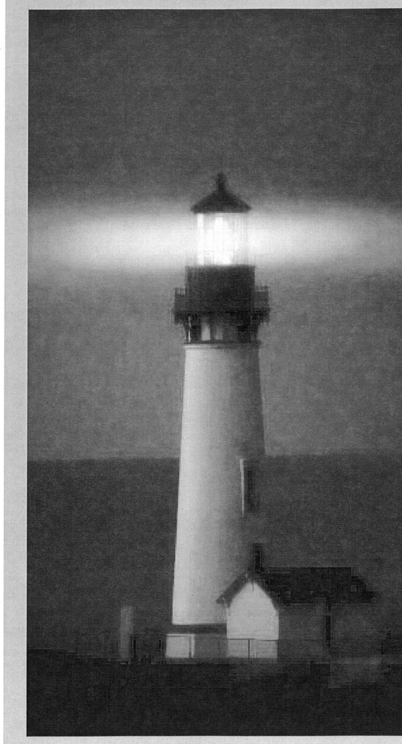




2003 Q2 Broadcast




Shell Hydrogen
Area covered by 100 km distribution around production
Boston
New York
Washington
Norfolk
Charleston
Savannah
Jacksonville
Orlando
Miami
Tampa
Charlotte
Nashville
St. Louis
Indianapolis
Thunder Bay
Duluth
Minneapolis
Milwaukee
Sioux Falls
Bismarck
Rapid City
Kansas City
Wichita
Denver
Albuquerque
Lubbock
Houston
Corpus Christi
Brownsville
Austin
San Antonio
El Paso
Phoenix
Tucson
Las Vegas
Salt Lake City
Boise
Spokane
Seattle
Reno
San Francisco
Los Angeles
San Diego
Orleans
Little Rock



The Way Ahead

Lighthouse projects, with …

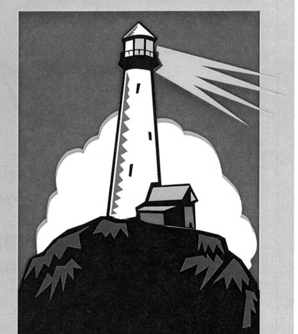
- Coordination mechanisms & incentives, that build …
- Supply chain confidence, supported by …
- Regulations, codes & standards, and …
- Promotion of public awareness

Substantial public-private partnerships

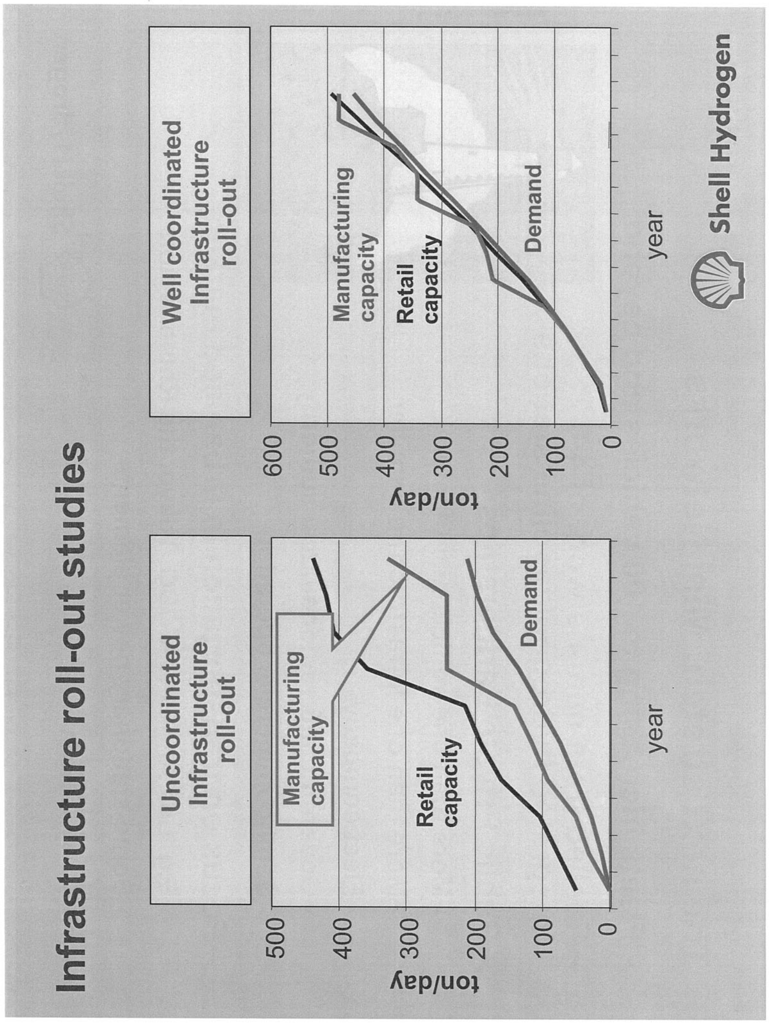
Shell Hydrogen

The next stretch: Mini Networks

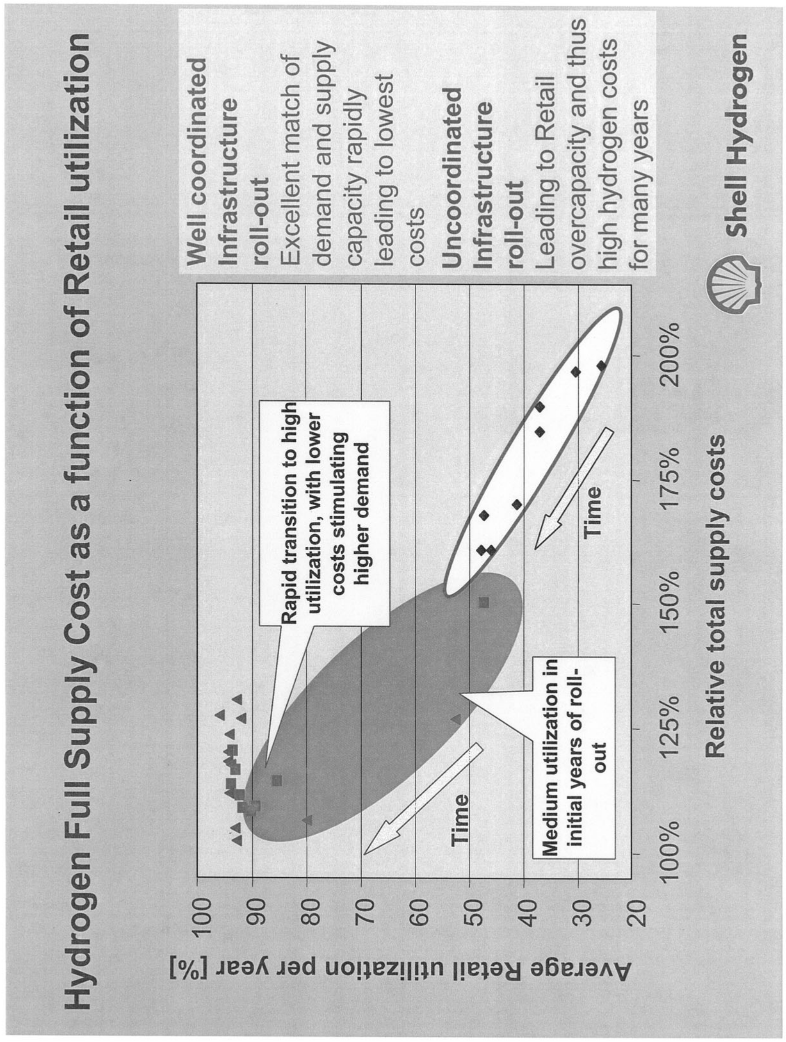
- Fleets increasing to 100 vehicles and beyond
- Fuelled from mini-network of 4-6 integrated hydrogen/gasoline stations
- Public Private Partnerships
  - More than one vehicle manufacturer
  - More than one infrastructure supplier
  - Fleet company
  - Government & regional/local authority
  - Semi-commercial operation
- Focus on transportation in urbanised markets
  - E.g. Los Angeles, NY/DC, Tokyo, the Rhine region
  - Some stationary power elements
- High visibility



Shell Hydrogen



Infrastructure roll-out studies
Uncoordinated Infrastructure roll-out
Well coordinated Infrastructure roll-out
ton/day
500
400
300
200
100
0
600
Manufacturing capacity
Retail capacity
Demand
year
Shell Hydrogen


Hydrogen Full Supply Cost as a function of Retail utilization
Average Retail utilization per year [%]
100
90
80
70
60
50
40
30
20
100%
125%
150%
175%
200%
Relative total supply costs
Rapid transition to high utilization, with lower costs stimulating higher demand
Medium utilization in initial years of roll-out
Time
Time
Well coordinated Infrastructure roll-out
Excellent match of demand and supply capacity rapidly leading to lowest costs
Uncoordinated Infrastructure roll-out
Leading to Retail overcapacity and thus high hydrogen costs for many years
Shell Hydrogen

BIOGRAPHY FOR JEROME HINKLE

Vice President for Policy and Government Affairs, National Hydrogen Association. During 2003 to early 2006, Mr. Hinkle was a senior advisor to U. S. Senator Byron Dorgan on a Brookings Fellowship from the Department of Energy. His work focused on energy and environmental policy, especially with regard to the various energy bills considered by the Congress from 2003–2005. He was responsible for helping form and manage the Senate's Hydrogen and Fuel Cell Caucus, a hydrogen industry working group and drafting and negotiating much of the hydrogen legislation in the *Energy Policy Act of 2005.* Besides hydrogen, he worked extensively on other titles of the Act, including Energy Efficiency, Coal, Indian Energy, and Vehicles and Fuels.

He served for 28 years at DOE and EPA in various capacities, including prototype engines and alternative fuels, environmental policy, international energy security and most recently as the senior economist for the U.S. Naval Petroleum Reserves. His interests include carbon management and renewable energy. His career also includes aerospace engineering and research physics, with a varied education—degrees in mathematics and physics from Miami University and public policy from the University of Michigan, with extensive graduate work in international politics and sociology.

Chairwoman BIGGERT. Thank you. And I'm sure we'll get to some of the other things in the questions.

STATEMENT OF DR. DANIEL GIBBS, PRESIDENT, GENERAL BIOMASS COMPANY

Dr. GIBBS. Chairman Biggert and Mr. Honda and Mr. Lipinski thanks for inviting me today.

Ethanol's here today and it fits our current infrastructure. The United States ethanol industry today produces about four billion gallons of fuel ethanol per year from corn grain. About 20 new plants will come on line this year adding another one billion gallons of capacity, and another billion is planned. Current ethanol production is about 300,000 barrels per day.

All United States' automobiles and light trucks can use ethanol today at 10 percent or E10 without any modification. In addition, about five million flex-fuel vehicles can use E85 or 85 percent ethanol gasoline or any mixture in between. So the infrastructure is there.

Flex-fuel technology is cheap. My figures of about $200 per car. Eight major auto manufacturers currently offer E85 vehicles.

To date the flex-fuel technology has been offered primarily in larger vehicles, I believe in order to obtain Clean Air credits. What we need to do is to put that technology together with hybrid technology, in my view, to give us E85 hybrids which could in principle get hundreds of miles per gallon of gasoline with the rest coming from ethanol.

The central problem then becomes how do we make enough ethanol and other biofuels to fill the demand. The national necessity and desirability of a large cellulosic ethanol industry is not yet widely recognized. I believe there's a lack of national urgency to make it happen in the time frame needed.

To be clear, we need to make not only ethanol as a substitute for gasoline, but we need to make all the other hydrocarbons for diesel fuel, jet fuel and for industrial chemicals and plastics. The only realistic nonfossil source for these materials is biomass in all its forms. These include energy crops like switchgrass, agricultural waste, paper from municipal solid waste, which is about 40 percent paper, forest and wood waste. If we use these sources, we'll provide a more diversified fuel and chemical base and create thousands of jobs.

The United States has substantial cellulosic resources, as does Canada, which can be developed if determination resources are there.

Let me just say a quick word about carbon. Carbon is not a bad thing. Carbon enables us to make large molecules for liquid fuels like gasoline, jet fuel and diesel which have a high power density. That's why we use them, that's why we make them. The question is where does that carbon come from? Does it come from beneath the ground from Saudi Arabia at high cost or does it come from domestic biomass? And that's a choice that is before us. So carbon is not a bad thing. Carbon from the air is a good thing. Carbon from beneath the ground is going to cause us problems in the future.

We're asked about the barriers to the cellulosic ethanol industry. Ironically, the great success of the corn ethanol industry constitutes a barrier to the development of the next phase for the cellulosic industry. And I hoped to show a slide, by the way, in the question and answer period.

The corn is cheap right now. Ethanol plants cost only a $1.50 per annual gallon of capacity. In contrast cellulosic ethanol plants with current technology cost about six times that much, and that is a severe barrier to the introduction of that technology.

In limited time, I won't go into the technology and logistical hurdles that are listed in the testimony, again just to give a couple of overview numbers here. The current corn crop is about 10 or 11 billion bushels a year, which is divided among ethanol, food products, animal feed, exports and carryover. Our probable limit for cellulosic ethanol or, I'm sorry, corn ethanol is about 11 billion gallons, which would be six percent of our 140 billion gallon gasoline supply. So we must go to cellulosic ethanol.

Biodiesel is a great fuel. This year it's only going to produce about 150 million gallons verses four billion for ethanol.

Let me just conclude by suggesting that there are a number of challenges. I think we need to collaborate with other countries. More than half the knowledge base is developed outside the United States. We need to collaborate with Canada. They've got a quarter of the boreal forest in the world. We need to have much more support for small business. And as indicated in the testimony, the support—federal support right now is very small.

We need to train people for this new industry.

And thank you.

[The prepared statement of Dr. Gibbs follows:]

PREPARED STATEMENT OF DANIEL GIBBS

1. How widely available is ethanol today, and how many cars can use it?

The United States ethanol industry produces about four billion gallons of fuel ethanol per year from corn grain. About 20 new ethanol plants will come online in 2006, adding another one billion gallons of capacity. Current ethanol production is about 300,000 barrels/day.

All U.S. automobiles and light trucks can use ethanol at 10 percent (E–10) without modification. In addition, about five million flex-fuel vehicles (FFVs) can use 85 percent ethanol (E85), gasoline or any mixture in between.

Flexfuel technology is cheap, about $200 per car, consisting of improvements to the fuel injector, gas line and gas tank. Eight major auto manufacturers currently offer E85 vehicles. Ethanol has about two-thirds the energy per gallon (76,100 Btu/

gal) as compared to gasoline (113,537 Btu/gal), but a much higher octane (100–105). To date, flex-fuel technology has been offered primarily in larger vehicles to obtain Clean Air credits. If flex-fuel technology and E85 were combined with hybrid technology, all available today, it would be possible to make E85 hybrids which could get hundreds of miles per gallon of gasoline, the rest coming from ethanol.

2. What are the obstacles to expanding the variety of feedstocks available for conversion to ethanol? Are these hurdles mainly market failures and other economic barriers or are they technical in nature?

The national necessity for a large cellulosic ethanol industry is not yet widely recognized. There is a lack of national urgency to make it happen in the time frame needed. High oil prices and global warming have come upon us rather suddenly, and both markets and government institutions are slow to react.

Commercialization of any new technology, and building new industries takes time and investment. Many different technical elements must be discovered, tried and perfected in a context which results in profitable businesses. As an example, it has taken the corn ethanol industry about 30 years to develop from small experimental plants to today's situation of 25–50 percent growth over the next year or so from the current four billion gallons/year.

Ironically, the current success of the corn ethanol industry and the low price of corn are barriers to the investment and risk-taking needed to jump-start the new cellulosic ethanol industry. Corn is currently cheap ($2.50/bushel), and the engineering technology for corn ethanol plants is so good that new plants cost only $1.50 per annual gallon of capacity. In contrast, cellulosic ethanol plants using current technology cost about six times that much for the same ethanol capacity (Iogen estimates).

Specific technical and logistical hurdles include:

(1) transportation of large volumes of low density biomass, e.g., 27 truckloads of switchgrass to make one truckload of ethanol;

(2) the need for safe, rapid pretreatments to process large volumes of raw biomass into cellulose and other components;

(3) large quantities of cellulase and other enzymes to convert cellulose to glucose for making ethanol. For example, a single 25 million gal/yr. ethanol plant would require 2,750 tons of cellulase enzymes. Adding just one billion gallons of cellulosic ethanol would require 40 such plants, with a total annual cellulase protein requirement of 110,000 tons/yr. For comparison, all U.S. industrial enzymes in 1994 amounted to about half that, 60,000 tons/year.

(4) new ways to solve the conflict between the need to build large plants for economies of scale, and the opposing need to transport low-density biomass over short (<30–40 mile) distances. Developing technology to enable smaller, cheaper cellulosic ethanol plants would have a large impact on lowering ethanol costs and promoting the widespread local development of biomass resources.

3. What is the largest technical hurdle for each of the following fuels: Corn ethanol, biodiesel, cellulosic ethanol? Does the current federal research agenda adequately address these technical barriers? What actions would most rapidly overcome these technical barriers?

Corn ethanol can be considered a fairly mature industry, in that there is good technology, reliable and experienced engineering firms and plant operators, and plenty of available capital for expansion. The problem for corn ethanol will be that its success will eventually raise the price of corn, and reach the limits of available corn supply. A typical U.S. annual corn crop is 10–11 billion bushels/year, divided among ethanol, food products, animal feed, exports and carryover. A probable limit for the ethanol fraction from corn is about four billion bu/yr., which would produce (2.8 gal/bu) about 11 billion gallons of ethanol, or about six percent of our current 140 billion gal gasoline supply.

Biodiesel is a good fuel with standards, great customer acceptance and a small but growing production industry. That industry will double production in 2006 to 150 million gallons. The main problem for biodiesel is limited feedstock. Biodiesel is made from animal fat or vegetable oil feedstocks including soybean oil, rapeseed (Canola) oil, and waste cooking grease. The fats or triglycerides are combined with an alcohol, usually methanol or ethanol, to make biodiesel and glycerol. Because the feedstocks come from food products, they are usually expensive or in limited supply. Given the demand for biodiesel, it would make sense to support federal and private research to greatly expand the production of plant oils, probably through biotechnology.

Cellulosic ethanol is more difficult to make than corn ethanol, because cellulose and biomass are structural materials, unlike corn starch which is a food material. The components of biomass: cellulose, hemicellulose and lignin, have evolved to resist breakdown for many years. However, the abundance of plant matter has driven the evolution of many microorganisms and genes dedicated to breaking down cellulose and extracting the glucose and other sugars. We can harness these genes and organisms to make a variety of petroleum substitutes from biomass, as part of the growing field of industrial biotechnology.

The chemistry, engineering and biotechnology needed to build this industry are complex.

Some specific technical hurdles were listed in response to question 2. Researchers at federal labs, notably NREL, ORNL and NCAUR, and at U.S. universities have addressed many of these issues over the years.

Much work has been done outside the U.S., in Canada, Sweden and Japan among other countries. More than half of the necessary knowledge base for biofuels has been and continues to be developed outside the United States. We need to find ways to use the best available technology from around the world, and not assume that our federal labs can provide all the answers, capable and dedicated as they are. We also need to foster training and international collaboration in developing alternatives to oil. Non-OPEC countries including the United States have a common need to develop cheap domestic fuel sources, or else face increasing economic costs and competition for scarce oil, as well as the effects of global warming.

Building a large and successful biofuels industry in the United States will require a sustained long-term commitment and adequate funding on the federal side. We need to leverage federal funds by making more federal support available to small business and commercialization efforts which can then attract venture capital and other nonfederal investment. In this way, we will build a healthy competitive industry with many players and different approaches.

DOE has wisely supported a number of important areas, including pretreatment research, enzyme development, and genomics, but still has a top-down central planning approach which needs to be augmented by more support of other innovative approaches developed outside the central plan. As an example, in 2005 the USDA/DOE Biomass Research and Development Initiative (BRDI) program received over 600 applications for $15 million of funding, or about 12 grants. The DOE SBIR program likewise offers minimal support for innovative projects in cellulosic ethanol and is inadequately funded. Outside grants in the range of $300,000 to $3 million would fill an important gap in enabling startups to demonstrate new technological approaches, and thereby attract the investment necessary for commercialization.

4. Some advocates suggest that biofuels should substitute for 25 percent or more of the Nation's transportation fuel use. Are there market or other barriers that policy might overcome to accelerate realization of the 25 percent biofuels goal?

As indicated above, we need to make this a national priority. The U.S. has achieved economic success in part by using large amounts of fossil fuels per capita. The downside is that we are now particularly vulnerable to price increases and supply disruptions, as well as incurring an increasing energy trade deficit.

To be clear, we need to make not only ethanol as a substitute for gasoline, but all the other hydrocarbons for diesel fuel and jet fuel (Rostrup-Nielsen, 2005), and for industrial chemicals and plastics. The only realistic non-fossil source for these materials is biomass in all its forms. These include energy crops like switchgrass (Gibbs, 1998; Greene et al., 2004), agricultural wastes, paper from municipal solid waste, and forest and wood wastes. Using all of these sources will provide a more diversified fuel and chemical base, and create many thousands of jobs. The United States has substantial cellulosic resources which can be developed if the determination and resources are there (Perlack et al., 2005).

Federal support for university and private R&D is vital, as indicated above. Commercialization, pilot, and demonstration plant subsidies are needed to move toward the goal of smaller and cheaper cellulosic ethanol plants. The level of public and private funding should over time reflect its importance to the United States, which is on a par with curing cancer and the Apollo program. In this case, there will be substantial private funding, once initial efforts begin to show some success. This is part of the "cleantech" investment sector which is growing rapidly.

Another barrier not discussed yet is developing trained people. Biomass research has heretofore been an arcane area pursued by a small number of scientists and engineers in academic and government labs. As with the biotechnology industry, growth brings the need for many people with specialized knowledge in the areas of biomass and biofuels. Dr. Lee Lynd et al. (1999) have recommended graduate programs in biocommodity engineering, including biotechnology, process engineering, and resource and environmental systems. Their paper provides a good overview of this emerging industrial area. Graduate and postdoctoral fellowships for study abroad in these areas would also be helpful in accessing the knowledge resources of other countries.

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General Biomass Company

General Biomass Company is an Illinois corporation founded in 1998 to develop and commercialize biomass technologies. We develop biotechnology for renewable fuels, with a focus on cellulase enzymes which are essential for the conversion of abundant cellulose wastes and biomass crops to low-cost glucose for the production of cellulosic ethanol, other biobased chemicals, and plastics.

General Biomass Company is a member of the American Coalition for Ethanol and the Illinois Biotechnology Industry Organization.

GLOBAL WARMING AND THE NEED FOR LIQUID FUELS FROM BIOMASS

D. Gibbs[1]

ABSTRACT

Given the magnitude of the systems which produce global warming and the attendant climate changes, it is important to develop and produce economically-viable carbon reduction technologies which can function on a sufficiently large scale within the next 20 years. Worldwide in 1993 there were 610 million vehicles, with an annual growth rate of 2.7%, or a doubling time of 26 years. Vehicle doubling times for populous emerging economies including China, India, Mexico, and the former USSR range from 6-10 years. Doubling motor vehicle use will add an additional 1 gigatonne C emissions to the atmosphere every year within 15-20 years. In the U.S., switchgrass could be converted to ethanol to produce 50 billion gal of ethanol, or the energy equivalent of 34 billion gallons of gasoline, 25% of 1994 U.S. liquid fuel consumption. The net carbon reduction effect of switchgrass-derived ethanol will depend on the energy sources and requirements for production, distribution and use. The low density of baled switchgrass and the wide geographic distribution of production sites pose problems to be solved, possibly through biomass compaction and large numbers of smaller, geographically distributed ethanol plants. Further development of ethanol separation technologies which use less energy, and technologies to recover and burn biomass lignin are needed to achieve the carbon-reduction potential of ethanol from biomass.

Keywords: global warming, climate change, liquid fuels, ethanol, biomass, switchgrass

INTRODUCTION

Given the magnitude of the systems which produce global warming and the attendant climate changes, it is important to develop economically-viable carbon reduction technologies which can function on a sufficiently large scale. Although the need to reduce the use of fossil fuels is understood, the development and effective deployment of alternative technologies is an immense task, one which will take at minimum a number of decades to carry out. It is moreover a task involving considerable technological, social and economic uncertainties. It will occur during a period of world population growth and potential shortages of water and food, compounded by weather events caused by global warming (Leggett, 1996). Many current and potential technologies will lessen CO_2 emissions, but the key question is whether any or all of them can be done on the scale

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necessary to have a significant impact on climate. A key element for effective deployment of technologies is their financial viability over the long term (Hart, 1997). It is highly appropriate to fund R&D, and to subsidize cleaner technologies, e.g. through a carbon tax, but large scale, long term development will require financial self-sufficiency. Development of such technologies will require considerable experimentation and failure as we attempt to find methods which are effective, safe, and have appropriate economic and social tradeoffs.

There is a premium on developing near-term (less than 20 years distant) technologies as global warming and energy use begin to accelerate. There is some evidence that warming can release stored carbon from a large carbon pool in boreal forest soils (Goulden et al., 1998), an instance of positive feedback which could increase the rate of warming. Large forest fires such as those in Indonesia, Mexico and Florida in 1998 provide positive feedback for global warming by quickly releasing carbon stored in living plants, while reducing for some years the leaf area available to sequester atmospheric carbon through photosynthesis. Additionally, atmospheric warming may trigger shifts in oceanic currents and climate which are not quickly reversible (Broecker, 1997). For these reasons, it is desirable to develop technologies for which there is some existing infrastructure and consumer demand, even though these may eventually be displaced by more sustainable technologies such as solar hydrogen.

The development of biomass technologies offers considerable promise in the near term, with the following benefits: 1) effective recycling of atmospheric CO_2, provided production and transportation do not consume excessive amounts of fossil fuels, 2) low cost, current technology to grow and harvest plants, 3) rural jobs, and 4) a fit into currently existing power and transportation infrastructures, specifically the replacement of coal and the use of biomass-derived ethanol to replace gasoline. The development of alternative liquid transportation fuels such as ethanol is particularly important because of the world-wide increase in vehicle miles driven. Potential costs and risks are 1) competition with food crops for land, water and fertilizer, 2) weather impacts, and 3) difficulty in dealing effectively with the low photosynthetic efficiency of plants and the resulting wide land area necessary for sufficient biomass production.

TRANSPORTATION AND GLOBAL WARMING

In the United States, passenger vehicles and trucks drove 2.4 trillion miles in 1994, more than doubling the vehicle miles travelled (VMT) in 1970. The average annual percentage change in U.S. VMT from 1989-1995 was 2.5%, a rate at which the number of VMT doubles every 28 years. The average annual VMT per vehicle was 11,700 miles, and average fuel consumption was 695 gallons in 1994, with a total fuel consumption of 140 billion gallons of gasoline and diesel fuel. U.S. passenger cars drove 67% of the VMT with an average fuel mileage of 9.14 km/l (21.5 mpg), with light trucks adding another 25% at 6.63 km/l (15.6 mpg)(American Automobile Manufacturers Association, 1996). Worldwide, in 1993 there were 465 million passenger cars and 145 million commercial vehicles in use, totalling 610 million vehicles, with an annual growth rate of 2.7%, or a doubling time of 26 years (United Nations, 1995). The United States had about 1/3 of these, totalling 194 million vehicles. Roughly another 1/3 were owned by western European countries and Japan.

Growth rates in vehicle ownership are higher in emerging economies, which translates into shorter doubling times. Statistics by country from the United Nations and the American Automobile Manufacturers Association show this clearly. Total vehicles in use in millions from the latest data available (1992-1994) and doubling times in years calculated for the preceding 5-7 years are: China, 9.5 million (6 yr doubling time); India, 6.2 (7 yr); Mexico, 12.3 (11 yr); former USSR, 11.5 (10 yr); Poland, 8.1 (9 yr); Turkey, 3.1 (6 yr); South Korea, 7.4 (3 yr) (American Automobile Manufacturers Association, 1995; United Nations, 1995). Thus developing and newly industrializing countries have much shorter doubling times for vehicle ownership, reflecting both rising personal income and starting from a smaller base number of vehicles relative to the population size. It is likely that the world average growth in ownership and VMT will tend toward these higher growth rates. Given the data cited, a world doubling time for vehicle ownership seems likely to move down from the current 26 years to 15-20 years.

Starting with 610 million vehicles in 1993 and conservatively assuming the current growth rate of 2.7%/yr, there should be 680 million vehicles in 1997. After a 15-20 year doubling time, there would be 1,360 million vehicles in the world. Assuming the average vehicle travels 16,000 km (10,000 miles)/yr, this would total 14 trillion VMT worldwide by 2012-2017. If the average fuel mileage is 8.5 km/l (20 mpg), this would consume 2.6 trillion liters (680 billion gal) of fuel. Assuming for simplicity that all of this is gasoline, and that each gallon produces a total of 22.5-22.9 lb CO_2 from production, combustion and distribution (Environmental Protection Agency, 1990; Energy Information Administration, 1996), this would amount to 8 billion short tons of CO_2 per year. Using a conversion of 1 tonne C /4.041 short tons CO_2 (Wuebbles and Edmonds, 1991), this is equivalent to 2 gigatonnes of carbon emissions. The current carbon flux from all fossil sources is about 6 gigatonnes C/yr (Brown et al., 1997). Doubling motor vehicle use will add an additional 1 gigatonne C/yr to the atmosphere every year within 15-20 years.

In principle, electric vehicles using electricity derived from solar energy could lessen the overall CO_2 emissions from vehicular transportation. However, electric vehicles currently face two severe limitations. First, the current electric power grid derives most of its energy from fossil fuels: coal, oil and natural gas, with most of the rest coming from nuclear plants and hydropower. Second, batteries for electric vehicles have a low specific energy, or energy per unit mass, compared to liquid fuels. The specific energy storage of gasoline is at least an order of magnitude greater than batteries made with current technology (Policy Implications of Greenhouse Warming, 1992).

Given the current manufacturing and fuel distribution infrastructure, and the inherent specific energy advantages of liquid fuels, internal combustion vehicles running on liquid fuel are likely to be prevalent over the next 10-20 years, and we need to address solutions which take account of this reality. Ethanol produced from cellulosic biomass has the potential to significantly reduce greenhouse gas emissions (Interlaboratory Working Group, 1997). Moreover, vehicles which can utilize ethanol as E85 are available today.
Ford has sold more than 12,000 Flexible Fuel Vehicles (FFVs) since 1993. These run on

either E85, unleaded gasoline or a mixture of the two, controlled by a sensor in the fuel system (Ford Motor Company, 1998). Ford plans to produce 250,000 FFVs over a 4-year period, and Chrysler will offer cars and vans capable of using E85 (Governors' Ethanol Coalition, 1997a). In the summer of 1997, 68 E85 filling stations were operating in the U.S., with another 113 planned to open by 1999 (Governors' Ethanol Coalition, 1997b). A recent DOE study estimates a market potential of 5 billion gallons of ethanol by 2010, assuming its use as a gasoline blending component only (Interlaboratory Working Group, 1997). The further development of E85 vehicles and the use of ethanol as a fuel for hybrid electric vehicles could increase this market further.

SOURCES OF ETHANOL

Current Ethanol Technology

The ethanol industry in the United States is likely to require significant technological change if it is to remain viable and grow over the next 10 years. In 1994, about 1 billion gallons of ethanol was used in gasoline in the U.S. Ethanol production capacity in January 1996 was about 1.5 billion gallons, including ethanol used for beverages and solvents as well as transportation fuel. Approximately 95% of this ethanol was produced from corn, with a yield of about 2.5 gallons of ethanol per bushel of corn. From 1988 to 1995, ethanol production used about 7% of the U.S. average annual corn production.

The profitability of ethanol production in the United States depends on the prices of corn as an input, the prices of the products: ethanol and DDGS (distiller's dried grains and solubles) used as livestock feed, and federal and state subsidies for ethanol. Apart from political uncertainties over subsidies, the major risk to profitable ethanol production is the price of corn. In essence, it is unprofitable to make ethanol from corn when the price of corn exceeds \$4.00-\$4.50 per bushel, given current subsidy levels. In the summer of 1996, corn prices went briefly over \$5.00 per bushel, compared to an average price of \$2.30/bushel for 1988-1995, and ethanol prices also increased to \$1.50-1.80/gallon (Chemical Marketing Reporter, 1996). In Minnesota, at the peak price of corn, the net profit per gallon of ethanol produced was negative \$0.42/gallon (not counting the Minnesota state subsidy of \$0.20/gallon). Without the federal gas tax credit for ethanol, it would have been negative \$0.96/gallon (Office of the Legislative Auditor, 1997).

This corn price spike illustrates the vulnerability of corn-based ethanol from an economic point of view. Firstly, 1 billion gallons of ethanol provided approximately 0.1% of the United States' energy needs in 1994, compared to 39% from petroleum (Office of the Legislative Auditor, 1997). Expanding this ethanol contribution to 1% would consume 70% of the U.S. corn crop and raise the price of corn. Secondly, corn prices are likely to rise due to increasing exports. China alone is projected to have a grain production/ consumption deficit of 100 million tons in 2000, and 200 million tons in 2010 (Brown, 1995). Every demand increase of 100 million bu of corn raises the price by \$0.05/bu . An additional annual demand of 100 million tons of corn, or 3600 million bu/year, could lead to a price increase of 36 x 0.05 or \$1.80/bu by the year 2000, assuming no additional sources of supply. The historical average price of corn from 1989-1996 is \$2.55/bu (Office of the

Legislative Auditor, 1997). Thus corn could cost \$2.55 + 1.80 or \$4.35/bu by the year 2000, clearly at the margin of profitability for low-volume (current) ethanol production with subsidies. Many factors influence this hypothetical calculation, including weather events and increased food demand from countries other than China (Brown, 1995). In any case, expanding ethanol production to a level which could substitute for a significant fraction of current U.S. gasoline use would raise corn prices, with corn feedstock prices becoming a limiting factor at some point.

Ethanol from Lignocellulosic Biomass

A potential solution to this problem is a change to cellulose-based ethanol production using herbaceous energy crops (HEC) or short rotation woody crops (SRWC) as feedstocks (Lynd et al., 1991; Wyman et al., 1993). These materials consist of cellulose and hemicellulose, which can be hydrolyzed to yield glucose and pentose sugars, which can be used as fermentation substrates for ethanol. In addition, lignocellulosic biomass contains lignin, which can serve as a boiler fuel for process heat or electricity generation. Much research has been supported by the U.S. Department of Energy (DOE) at the National Renewable Energy Laboratory (NREL) and the Oak Ridge National Laboratory (ORNL) on the economics, growth, harvesting and conversion of lignocellulosic biomass to ethanol (Graham, 1994; Wright, 1994; McLaughlin et al., 1996).

Switchgrass is a tall perennial grass which grows from Canada to Central America. Substantial research has been done on the economics, breeding, cultivation and harvesting of switchgrass for use as an energy crop (Wright, 1994; Taliaferro and Hopkins, 1996; Teel, 1996). Switchgrass requires lower fertilizer inputs than corn, for example nitrogen at 50 kg/ha/yr vs. 135 kg/ha/yr for corn (Ranney and Mann, 1994). This lowers costs, reduces runoff pollution, and saves on energy costs and carbon emissions associated with fertilizer production. Switchgrass can produce 1 or 2 crops per year, every year, in contrast to short rotation woody crops, which are harvested every 4-6 years, and conventional forests, which may need 10 years or more between harvests. Grasses are potentially better able to adapt to climate change than forests, a factor which may be important in the future (Bright, 1997).

As a perennial grass, switchgrass can be harvested by mowing, leaving the roots in place to hold the soil. It is used as a ground cover on erosion-sensitive lands and is drought-tolerant. An analysis at ORNL (Graham, 1994) estimates that 54 million hectares (133 million acres) of land in the U.S. are suitable for switchgrass production, but marginal for conventional annual crops such as corn. This land could yield 696 million Mg (767 million tons) of dry herbaceous biomass per year at an average yield of 12.9 Mg/ha (5.8 tons/acre). If this amount of switchgrass were entirely converted to ethanol at a yield of 280 liters/Mg (McLaughlin et al., 1996), this would produce 195 billion liters (51 billion gal) of ethanol, or the energy equivalent of about 34 billion gallons of gasoline. This is approximately 25% of 1994 U.S. liquid fuel consumption. Ethanol/ gasoline equivalents are based here on energy contents of 76,100 Btu/gal for ethanol and 113,537 Btu/gal for gasoline (Interlaboratory Working Group, 1997) for an energy equivalence ratio of 0.67. For engines optimized to run on ethanol, this ratio increases to 0.8 (Lynd et al., 1991).

Other estimates for U.S. cellulosic biomass capacity are higher. Lynd et al. (1991) estimate a cellulosic ethanol production potential of 12.4-26.5 quad (1 quad = 10^{15} Btu) or 160-350 billion gal/yr based on cellulosic wastes, idled and potential cropland and forest land. Using an estimate of 77 million ha and a yield of 20 Mg/ha, Wyman et al. (1993) project a U.S. energy crop capacity of 1.5 billion Mg/yr. Adding to this MSW, underutilized wood and crop residues, they project a total of 2.3 billion Mg of cellulosic feedstock/ yr, potentially producing > 1 trillion liters (260 billion gal) of methanol and ethanol annually (yield assumed is 430 l/Mg or 103 gal/ton).

Hall et al. (1993) estimate a global potential for plantation biomass (wood and grass) of 890 million hectares, with a potential yield of 15 Mg/ha (6.7 tons/acre). This is probably an upper limit, equivalent to 10% of the land area presently in cropland, forests, woodland and pasture, or 7% of the total world land area. This quantity of biomass would provide energy exceeding 260 exajoules/yr, or more than 80% of global commercial energy use in 1985. If entirely converted to ethanol at 280 l/Mg, it would yield 3.7 trillion liters (1 trillion gal), the energy equivalent of about 670 billion gal of gasoline.

PROBLEMS AND SOLUTIONS

Biomass-derived ethanol meets the criterion of being potentially deployable on a large enough scale to have an impact on the fossil-fuel carbon emissions which cause global warming, and it has a significant current technology base with many opportunities for future improvement. Large-scale deployment and commercial success for switchgrass-derived ethanol will require solutions to problems in at least two areas: (1) the low density of baled switchgrass, and (2) the energy required to separate ethanol from a dilute fermentation solution.

Plants have a low photosynthetic efficiency, meaning that the amount of incident solar radiation fixed into chemical bonds is relatively low, resulting in a fuel product which has a lower energy per unit volume than coal or oil. The practical implication of this is that a wide land area including many production sites will be needed to produce enough biomass to achieve a significant reduction in carbon emissions. The wide geographic distribution of production sites, combined with the low density of baled switchgrass creates a need for transportation of large amounts of biomass. Transportation using trucks powered by fossil fuels (diesel) creates greenhouse gases and adds to the cost of delivered feedstock. For example, 6'x5' round bales of switchgrass have a density of 133 kg/m^3. A truck with a volume of 35 m^3 could carry about 4.66 metric tons of switchgrass. Assuming an ethanol yield of 280 liters/metric ton (67 gal/ton)(McLaughlin et al., 1996), this amount of switchgrass would produce 1300 liters of ethanol, occupying a volume of 1.3 m^3, giving a volumetric ratio of switchgrass to ethanol of about 27. Put another way, it takes 27 truckloads of switchgrass to produce one truckload of ethanol. This volumetric ratio problem is more severe for low-density biomass than for corn. Assuming a yield of 2.6 gal ethanol /bushel of corn, the comparable volumetric ratio is about 3.6:1.

Possible ways to reduce biomass transportation energy and storage costs are:
a) Compaction or densification using mechanical pressure to reduce the volume of a given

quantity of biomass (KTBL, 1984; Ortiz et al., 1996) . Large-scale transportation and storage of biomass will probably require some form of compaction. Densified biomass would also be more suitable for lower cost means of transport such as rail or barge. This is useful also for coal substitution in power generation. Problems to be solved are throughput and the energy required.

b) Large numbers of smaller, geographically-distributed ethanol plants, so that large numbers of truck trips carrying switchgrass bales are replaced by fewer truckloads of ethanol out and chemical inputs in. Current thinking is that larger corn-based ethanol plants are more efficient, because of factors such as the more efficient use of labor and capital, and opportunities for reuse of process heat. A change to biomass-based ethanol plants will need to take into account the transportation volume problem noted above, and to consider the possible advantages of smaller biomass ethanol plants deployed in greater numbers. Problems to be solved are economies of scale vs. transportation costs, development of efficient and economically viable process technologies, personnel for small plants, automation and control, waste disposal, and safety.

Ethanol purification requires considerable amounts of energy, whether the ethanol is derived from corn or biomass. Possible ways to reduce energy use and net carbon production associated with ethanol purification are:
a) Distillation and separation technologies which use less energy per gallon of ethanol produced.
b) Recovering and burning lignin to produce process steam and electricity. Apart from the potential reduction of carbon emissions, lignin use technologies could substitute at least partially for the value of coproducts created by wet mill and dry mill corn ethanol plants.

Solving these problems could be of significant benefit to establishing a new and larger non-fossil ethanol industry in the United States, with the potential to export technology and components to other countries. Deployment of these technologies on a sufficiently large scale could significantly reduce the net carbon emissions from the transportation sector.

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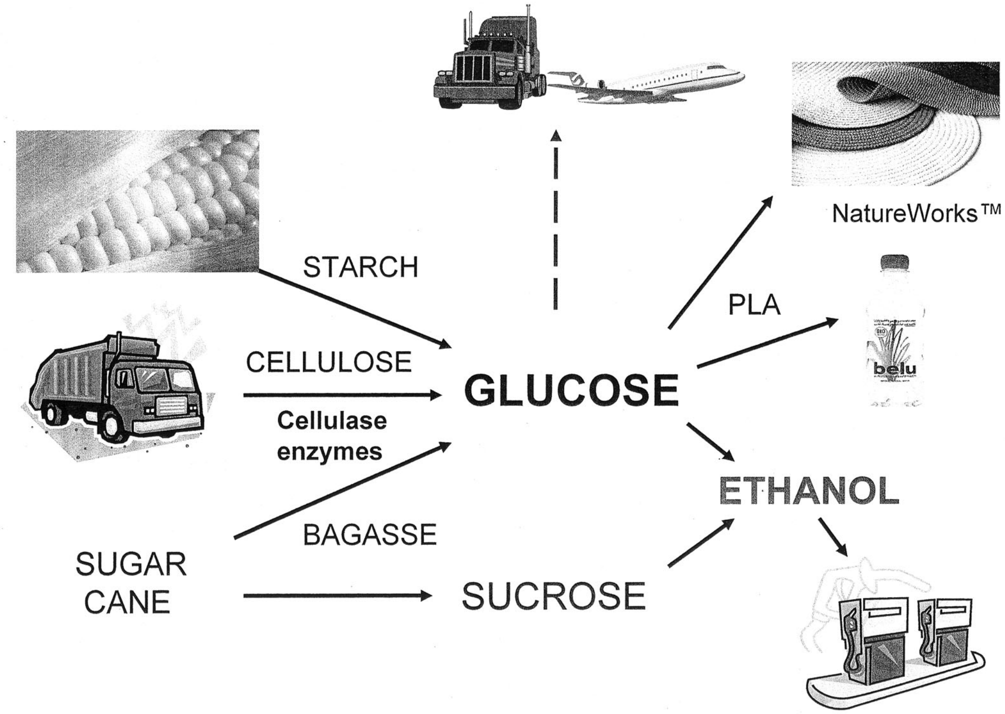
General Biomass Company



BIOGRAPHY FOR DANIEL GIBBS

Daniel Gibbs is President of General Biomass Company. His research interests are in cellulase enzymes, paper waste utilization and cellulosic ethanol production. He has over 20 years of experience in basic research in biological sciences at Stanford, the University of Washington, and DePaul University, and five years of experience in pharmaceutical and diagnostic R&D at Abbott Laboratories, including new technology development and evaluation, patent analysis and evaluation, bioinformatics and software development. He is the author of nine scientific papers including "Global Warming and the Need for Liquid Fuels from Biomass," presented at BioEnergy '98, a paper on ethanol from switchgrass, a renewable energy crop. He was an invited speaker on biomass ethanol at the American Coalition for Ethanol annual meeting. At Abbott Labs, he worked in Pharmaceutical Division R&D on bioinformatics, genomics and gene sequence databases, and in Diagnostics Division R&D on software and patent support for process control of fluidic and chemical systems. He was previously Associate Professor of Biological Sciences at DePaul University and received an NIH grant for research on insect neuroendocrinology. He was an NIH Postdoctoral Fellow at the University of Washington and an NIH Predoctoral Fellow at Stanford. Dr. Gibbs received a B.A. in Biology from Wesleyan University and an M.A. and Ph.D. in Biological Sciences from Stanford University.

Chairwoman BIGGERT. Thank you very much, Dr. Gibbs. Mr. Lovaas.

STATEMENT OF MR. DERON LOVAAS, VEHICLES CAMPAIGN DIRECTOR, NATURAL RESOURCES DEFENSE COUNCIL

Mr. LOVAAS. Thank you. Chairman Biggert, Ranking Member Honda, thanks for the opportunity to testify today.

America's addicted to oil, the President said in his State of the Union. Transportation drives this fact, accounting for more than two-thirds of U.S. oil demand. Our cars and trucks specifically account for 40 percent of total demand. If trends continue, our thirst for 21 million barrels a day of oil will grow by a third by 2030. Consequences include dependence on hostile regimes, a huge transfer of wealth overseas and global warming pollution.

Drivers and consumers on a roll price roller coaster. Not since marketplace turmoil in the '70s have prices increased as much as the early 2000's. Prices at the pump are approaching all time highs.

The EIA confirmed that high prices are here to stay in their 2006 Outlook. Their reference case projects that oil prices will drop from $70 levels of recent months to $47 in 2014 only to increase to $54 per barrel, $21 higher than their 2005 Outlook by 2025.

The last time prices spiked like this the effect was profound as described in a recent report by auto analyst Walter McMannis. Drivers began shunning large gas guzzling cars made by American automakers in favor of fuel efficient cars built in Japan and Germany. Between 1978 and '81 U.S. automaker sales dropped by 40 percent to a decline of about 5.2 million units. The second oil shock came six years after the first shock which prompted Congress in 1975 to adopt fuel economy standards. This law required a doubling in passenger car efficiency to 27.5 mpg between 1975 and '85. Some argue that the United States' big three share loss in this period would have been even worse had they not been forced to begin building at least some more fuel efficient cars to comply with the new law.

History is beginning to repeat itself, unfortunately. Domestic automakers are suffering due to over reliance on fuel inefficient vehicle offerings. GM sales slide 12 percent in May compared to a year ago. The collective Detroit automakers share drooped to 52.9 percent. Meanwhile, they may only account for one to two percent of total United States' sales, but hybrid sales have doubled or nearly so for every year since the turn of the century. A variety of such technologies can break our old addiction.

First, off-the-shelf improvements to conventional vehicles such as four valve cylinders, variable valve timing, automatic engine shut-off, slicker materials for reduced drag, better tires and five and six-speed transmissions. The cumulative effect in an average SUV would yield at least a one-third improvement in fuel economy performance. So that's conventional technologies.

Hybrid electric vehicles, hybrids fueled by electricity and gasoline. They run the gambit from mild hybrids to full ones. Although costs of the technology have come down since the first one was unveiled in 1999, there is still a costly proposition. However, a recent analysis found that $3 per gallon changes everything. Opting for more efficiency is nearing cash flow neutrality for consumers. That's good news.

Three. Flex-fuel vehicles. They ran on alcohol fuel and/or gasoline. Alcohol fuel being a fuel like ethanol. This adds modest expense to manufacture of automobiles. One estimates places per vehicle cost at a modest $100 to $200. Draw backs include the fact that blending ethanol in low proportions to gasoline increases smog forming pollution. Ethanol also has lower energy content so for it to be a cost effective alternative, it must be at least 25 percent cheaper than gasoline.

Also, less than 2.6 percent of American autos are flex-fueled and there is a infrastructure lag that's even great. Since 700 stations offer ethanol, less than one-half of one percent of gas stations.

Four, plug-in hybrids. Rely more heavily on electricity as a fuel, although they can also run on gasoline or both alcohol fuel and gasoline if they're flex-fueled, too. Batteries remain expensive and have limited ranges. A hybrid might cost as much as $4,000 more than a similar conventional vehicle. A plug-in with a range of 20 miles could cost $6,000 more. And one with a range of—20 that's 20 miles actually. One with a range of 60 miles could cost $10,000 more. Now the limited range itself may not be an issue since 31 to 39 percent of annual miles driven are for the first 20 miles of daily driving.

Plug-ins don't suffer from the chicken and egg problem that plagues hydrogen. They are powered by the existing electrical grid. So there are advantages. And if they use surplus power or the grid is powered by clean renewables, pollution would drop.

So, in summary, to set America free of oil we must invest in all of these technologies, a message you've heard before. Consumers appreciate choices and the cumulative effects are likely to be great. For example, as Dan mentioned, the combination of an E85 FFV and a hybrid vehicle like the new Ford Escape E85 FFV.

Two of the best ways to make sure that these choices are available to consumers are to:

1. Enact H.R. 4409, the *Fuel Choices for American Security Act,* sponsored by Representative Kingston, Engel and Saxton; and

2. To enact the Boehlert Markey Amendment to increase fuel economy performance.

These bills boost new technologies like the ones I described and they're effective policy responses to oil addiction.

Thank you.

[The prepared statement of Mr. Lovaas follows:]

PREPARED STATEMENT OF DERON LOVAAS

"America is addicted to oil," the President said in his State of the Union. He was right. We're hooked. Why is that the case?

Transportation drives our addiction. For starters, we're taking more trips. More Americans rode trains and buses 80 years ago, and transit use spiked during World War II. Then it plummeted, leveling off at less than half of its peak level. Meanwhile vehicle miles traveled climbed steadily, and are at the three trillion per year mark.[1]

Increasing travel by private vehicle is exacerbated by two other trends: An increasingly wasteful fleet of cars and trucks and pitifully small use of alternatives to fuels made from oil.

Thanks largely to the proliferation of larger vehicles—particularly SUVs—improvements in fuel economy of the fleet stalled in 1988. The largest recent jump in performance happened in the late 70s, driven by policy and consumer choices in reaction to embargoes and price runups.[2]

The third factor is alternative fuel use, or rather non-use, in transportation. We fill our tanks with fuel, and 97 percent of the time it's a petroleum-derived liquid, mostly gasoline.

Meanwhile, domestic production peaked and has been declining steadily since 1970. Currently, we produce about 8.9 million barrels a day but that's only enough to meet about 40 percent of America's daily consumption of 21 million barrels daily.[3]

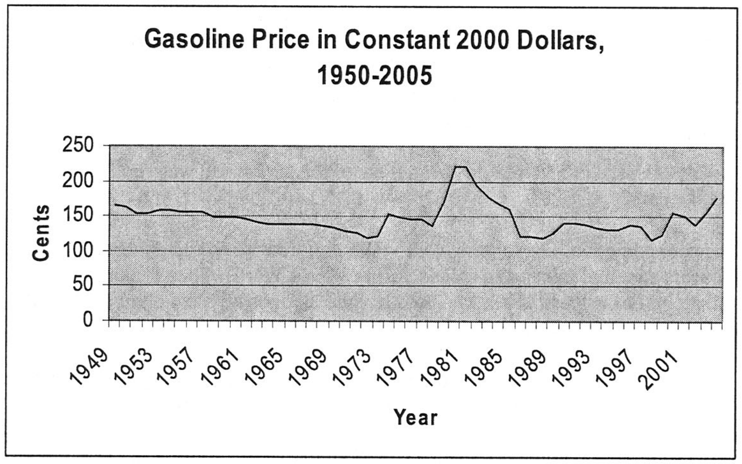
The Oil Price Roller Coaster

Not since the embargo and marketplace turmoil in the 1970s have prices increased as much as in the early 2000s. In fact, gasoline prices are approaching all-time highs (see graph below).

[1] Based on Federal Highway Administration and American Public Transportation Association figures.

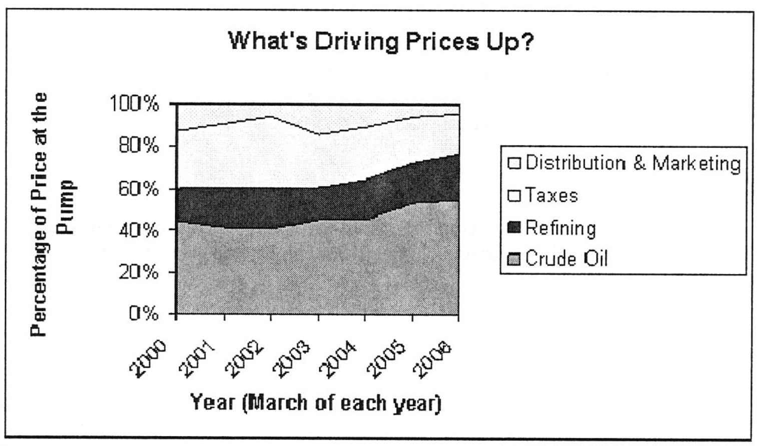
[2] U.S. EPA, "Light-Duty Automobile Technology and Fuel Economy Trends: 1975 Through 2003."

[3] Energy Information Administration (EIA), Department of Energy.



Source: EIA

Underpinning soaring prices are the oil markets, as shown in the graph below.



Source: EIA

The fundamentals underpinning the oil price trends are described in a recent report by NRDC, the Office for the Study of Automotive Transportation and the University of Michigan Transportation Research Institute:[4]

> Most analysts agree that market fundamentals of high demand and limited supply, and not speculation or market hysteria, are the primary reason for today's high oil prices. These prices can be explained, in part, by explosive growth in oil demand, especially from China. Oil demand has grown a robust five percent since 2003, despite a doubling of oil prices during that period. It appears likely

[4] "In the Tank: How Oil Prices Threaten Automakers' Profits and Jobs," July 2005.

> that increased global oil demand and tight global oil supplies will keep fuel prices high for the next several years.
>
> There is little spare oil production capacity to cushion a sudden loss in supply and the mix of easily extractable crude oil is moving away from "light, sweet" toward more "sour" grades that fewer refineries can handle. Considering these factors, oil prices may abruptly jump even higher, as happened during the first two oil crises of 1973–75 and 1979–81. But unlike these last two oil crises, important oil market fundamentals could favor a higher price lasting for much longer—and perhaps becoming a permanent feature of the environment.
>
> One reason we can expect sustained high oil prices is that we have limited spare capacity. Historically, producers were accused of holding back supplies when prices rose. But most industry experts agree that the Organization of the Petroleum-Exporting Countries (OPEC) and other suppliers are now pumping at or near the upper limits of their capability. Indeed, there are concerns that rapid exploitation degrades the long-term viability of some oil fields.[5] Spare capacity, often used to cushion oil price spikes, is essentially gone.

The Energy Information Administration (EIA) confirmed that high prices are here to stay in the Annual Energy Outlook 2006 (AEO 2006). The reference case projects that oil prices will drop from the $60–$70 levels of recent months to $47 in 2014, only to increase to $54 per barrel—$21 higher than the 2005 outlook—in 2025. And the high price case actually flirts with the $100 per barrel level in 2030.[6]

Déjà vu All Over Again: Prices Affecting Auto Sales

Of course, price fluctuations are not a new thing. The last time oil prices leapt to this level the effect was profound, as described again in the "In the Tank" report:

> [D]rivers also began shunning large, gas guzzling cars made by American automakers in favor of fuel-efficient cars built in Japan and Germany. Between 1978 and 1981, U.S. automaker sales dropped by 40 percent, a decline of about 5.2 million units.[7] The second oil shock came six years after the first shock, which Congress in 1975 to adopt fuel economy standards (under the *Energy Policy and Conservation Act of 1975,* known as "EPCA"). This law required a doubling in passenger car efficiency to 27.5 mpg between and 1985. Some argue that the U.S. Big Three's share loss in this period would have been even worse had they not been forced to begin building least some more fuel-efficient cars to comply with the new law.
>
> Employment plunged along with automobile sales. It dropped 30 percent from 1978 to 1982, for a total loss of more than 300,000 jobs in direct auto and part manufacturing jobs—and even more jobs were lost if auto-related jobs are considered. And the Detroit Big Three suffered record losses. In 1980, GM lost $762 million, Ford lost $1.7 billion, and Chrysler lost the most, $1.8 billion. Chrysler's situation was so bad that in 1979 Congress agreed to bail out the company with $1 billion in loan guarantees.[8]
>
> Worse, when gasoline prices returned to pre-shock levels, U.S. automakers failed to regain their lost market share in passenger cars. Indeed, the three periods of sharpest growth in import market share, 1973–75, 1979–81, and 2003–present, coincide precisely with the largest increases in per gallon gasoline prices.

History is beginning to repeat itself. On the one hand, sales of larger vehicles, like the overall economy, have been remarkably resilient in the face of high prices: In 2003, the share of sales for large light-duty vehicles was 73.3 percent and it edged down slightly to 73.1 percent in 2005.[9]

But slicing the data more finely yields a fundamental shift in auto sales. Based on data from the Planning Edge, the graph below shows tremendous growth in the crossover utility vehicle segment, while large SUV sales took a hit in 2005.

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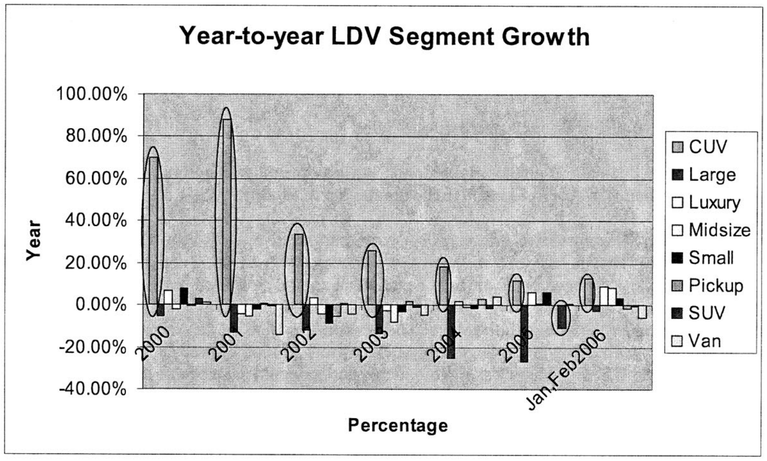
[5] Simmons, Matt. *Twilight in the Desert: The Coming Saudi Oil Shock and the World Economy,* John Wiley & Sons (2005).

[6] EIA, AEO 2006.

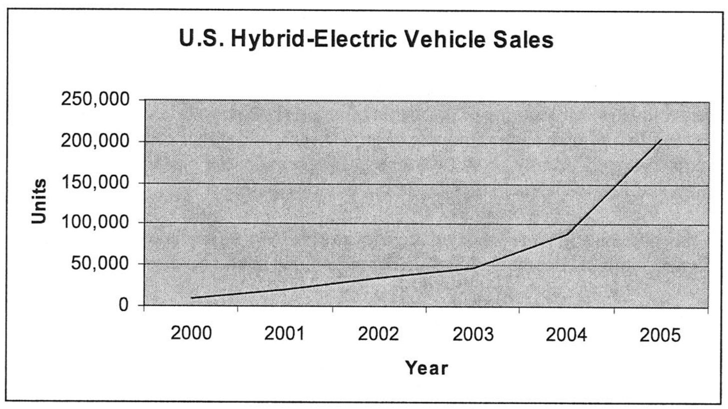
[7] The second oil shock came six years after the first shock, which Congress in 1975 to adopt fuel economy standards (under the *Energy Policy and Conservation Act of 1975,* known as "EPCA"). This law required a doubling in passenger car efficiency to 27.5 mpg between and 1985. Some argue that the U.S. Big Three's share loss in this period would have been even worse had they not been forced to begin building least some more fuel-efficient cars to comply with the new law.

[8] Doyle, J., *Taken for a Ride,* the Tides Center, 2000, p. 173–4.

[9] Ward's Automotive Reports, 2003–2006, monthly.



And while they only account for one to two percent of total U.S. sales, the other trend that has received a great deal of press attention is soaring sales of hybrid-electric vehicles. In fact, hybrid sales have doubled or nearly so every year since the turn of the century:

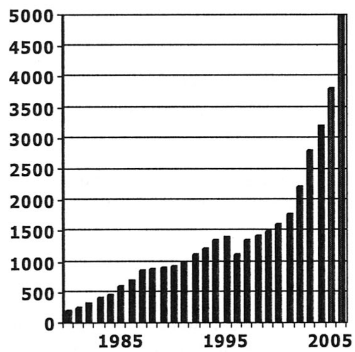


Source: Business Week Online

Biofuels

Biofuels are liquid, alcohol fuels derived from plant matter. The U.S. primarily uses ethanol using corn as a feedshock. While our transportation sector is 97 percent dependent on petroleum-derived fuels—especially gasoline—ethanol makes up for the remainder.

And it has been growing rapidly, as shown by the chart below (in millions of gallons per year of corn ethanol):



Source: Renewable Fuels Association and the American Council on Renewable Energy

Beyond corn, the next generation of biofuels is being developed. Specifically, ethanol derived from the cellulose of plants offers promise. The President referred to this emerging technology in his 2006 State of the Union speech when he talked of making ethanol from switchgrass. As explained in the NRDC report "Growing Energy":

> Cellulosic biomass is basically all the parts of a plant that are above ground except for the fruit and seeds, such as corn, wheat, soybeans, and rapeseed. Technically, cellulosic biomass is the photosynthetic and structural parts of plant matter. Other examples of cellulosic biomass include grass, wood, and residues from agriculture or the forest products industry. Most forms of cellulosic biomass are composed of carbohydrates, or sugars, and lignin, with lesser amounts of protein, ash, and minor organic components. The carbohydrates, usually about two-thirds of the mass of the plant, are present as cellulose and hemicellulose—thus the term cellulosic biomass.[10]

Advantage of this process and its reliance on feedstocks besides corn include dramatic increases in energy and environmental benefits, including big reductions in carbon dioxide emissions.

Heartening Trends, But Slow Progress Overall

In percentage terms trends in hybrids and biofuels are impressive. But in absolute terms they barely make a dent in our oil addiction. A higher price plateau notwithstanding, current demand of about 21 million barrels per day is projected to increase by more than a third by 2030.[11]

This has serious economic consequences. First, we're already transferring a huge amount of wealth overseas thanks to a ballooning trade deficit. The economic costs would be steeper, if not for the fact that our policy response to the energy crisis in the '70s helped to drive the oil intensity (a measure of barrels used to produce GDP) of our economy down by about one-third, providing better insulation from today's high prices. This is why demand has barely slackened and the economy hasn't slipped into recession.

However, these gains have slowed dramatically in recent years. It's clear why this is so in transportation—stagnating fuel economy and increasing travel. For electricity, it's due to the fact that there's just not much left to shift—we have pretty much weaned that sector off oil. This means that our economic shock absorbers are wearing thin once more.

Spiky, high prices have been a hardship for U.S. consumers, but the pain is more deeply felt in the developing world. According to the World Bank, a sustained oil price increase of $10 per barrel will reduce GDP by an average of about 1.5 percent in countries with per-capita income of less than $300, compared to a loss of less than .5 percent for developed countries.

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[10] Greene, et al., "Growing Energy: How Biofuels Can Help End America's Oil Dependence," December 2004.
[11] EIA AEO 2006.

And of course the consequences for national security are alarming too, as described a joint NRDC–Institute for the Analysis of Global Security report *"Securing America: Solving Our Oil Dependence Through Innovation"* (attached).

Breaking the Oil Addiction Requires New Policies

Policy-makers must provide frustrated consumers with a means to react to persistent price signals. Thankfully, this doesn't require a 12-step program. It does require significant policy reforms.

Many of the necessary reforms are included in a bill supported by the Set America Free coalition. H.R. 4409, the *Fuel Choices for American Security Act,* currently has 75 co-sponsors and has four components:

- A national oil savings requirement starting at 2.5 million barrels of oil per day within ten years and increasing over time, achieved through a menu of existing and new authorities and incentives;
- federal manufacturer retooling incentives for production of efficient vehicles and authority to set efficiency standards for tires and heavy duty trucks;
- programs that increase fuel choice in the transportation sector; and
- a national energy security media campaign to educate the public about oil dependence.

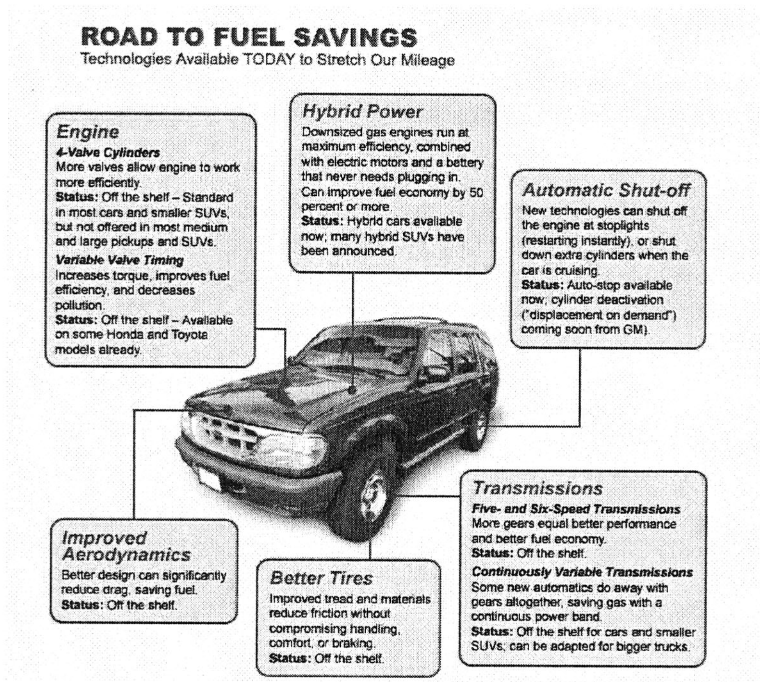
The targets can be achieved via oil savings from any sector, any technology. Much of the savings will come from transportation, which is responsible for about two-thirds of our oil consumption and is utterly dependent on petroleum.

Overview of Technologies

There are a variety of options available to reduce our oil dependence. Some of the advantages and challenges posed by each one are summarized below.

- Off-the-shelf improvements to conventional vehicles: As summarized in the graphic below from NRDC's web site, these include improvements such as four-valve cylinders, variable valve timing, automatic engine shut-off, slicker materials for reduced drag, better tires and five- and six-speed transmissions. The Union of Concerned Scientists has calculated that making similar improvements to an average SUV yields at least a 31 percent improvement in fuel economy performance.[12]

[12] Union of Concerned Scientists, "Building a Better SUV," *http://www.ucsusa.org/clean_vehicles/cars_pickups_suvs/building-a-better-suv.html*



- Hybrid-Electric Vehicles (HEVs): These increasingly popular cars and trucks are fueled by electricity and/or gasoline. They run the gamut from mild hybrid models (for example, Chevrolet Silverado comes in a hybrid version) to full ones (Toyota Prius). Although costs of the technology have come down since the first hybrid was introduced in 1999 by Honda (the Insight, now discontinued), and prices of gasoline have come up, these fuel-sippers are still a relatively costly proposition for consumers.

  Consumer Reports recently analyzed five-year costs (purchase, sales tax, insurance, maintenance, financing) and benefits (federal tax credits, lower fuel costs, higher resale value) of five hybrids and found that only two penciled out, barely: The Toyota Prius and the Honda Civic. Their analysis assumed gas prices rising over time to $4 per gallon.[13]

  On the other hand, a recent Consumer Federation of America report found that a threshold has been crossed with $3 per gallon gasoline. Their analysis shows that consumers no longer pay a premium for efficiency. Opting for a more efficient technologies including hybrid-electric engines should be "cash-flow neutral" for consumers, according to this analysis.[14]

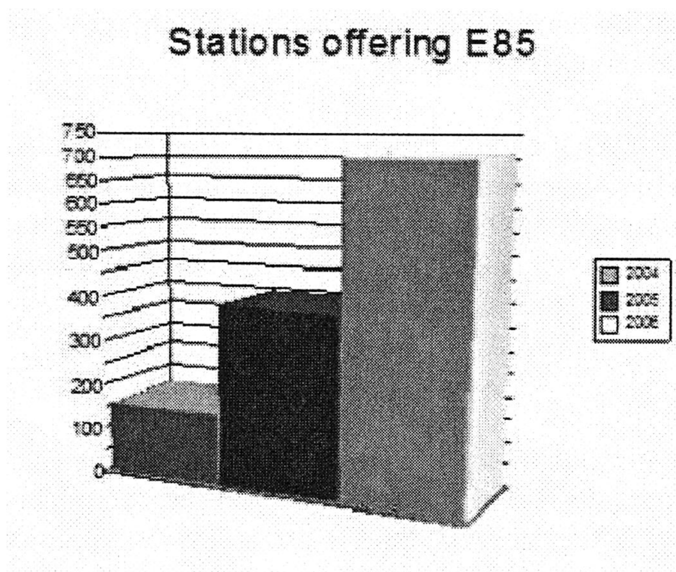
- Flexibly-Fueled Vehicles (FFVs): These vehicles are capable of running on a mixture mixture of alcohol fuels such as ethanol and gasoline. This adds some expense to the manufacture of automobiles, specifically to ensure that tanks and fuel hoses are able to tolerate alcohol. One estimate places per-vehicle cost at a modest $100–$200.[15] There are other challenges with displacement of gasoline with ethanol. When blended in low proportions to gasoline, smog-forming pollution (oxides of nitrogen and volatile organic compounds) in-

[13] *Consumer Reports,* April 2006, "The Dollars and Sense of Hybrids."
[14] Cooper, Mark, "50 by 2030: Why $3.00 Gasoline Makes the 50 Mile per Gallon Car Feasible, Affordable and Economic," May 2006.
[15] "Ethanol Fact Sheet," American Petroleum Institute, March 23, 2006.

creases compared to gasoline. Higher blends such as E85 (85 percent ethanol, 15 percent gasoline) yield a cleaner-burning fuel.

Another drawback of ethanol is its lower energy content compared to gasoline. Due to the difference, for ethanol to be a cost effective alternative it must be at least 25 percent cheaper than gasoline.

Last but not least is the chicken-and-egg problem with this fuel: Precious few stations feature ethanol pumps. This is changing rapidly (see graph below) and resources for locating pumps are readily available (see *http://afdcmap2.nrel.gov/locator/FindPane.asp*). But the 710 stations currently offering this choice adds up to less than .5 percent of the total number of retail outlets.[16]



Source: http://e85vehicles.com/

- Plug-In Hybrid Electric Vehicles (PHEVs): These are vehicles which rely more heavily on electricity as a fuel, although they can also run on gasoline, or a blend of alcohol fuel and gasoline. Although Honda and Toyota remain skeptical due to marketing concerns (awareness has only recently become widespread that hybrids DON'T have to be plugged in), there is growing interest in these vehicles as a tool for breaking the oil habit. Significant challenges remain, however.

  First among these is battery technology. Batteries remain expensive and have limited ranges. So in spite of cost savings due to a smaller internal combustion engine and electrification of other vehicle components too, while an HEV might cost $2,500–$4,000 more than a similar conventional vehicle, a PHEV with a range of 20 miles would cost $4,000–$6,000 and one with a range of 60 miles would cost $7,400–$10,000.[17]

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[16] According to the *National Petroleum News* (May 2005) as quoted by EIA there are 168,987 gas stations in the U.S.

[17] EPRI, 2001 as quoted in Plotkin, Steven, "Grid-Connected Hybrids: Another Option in the Search to Replace Gasoline," TRB 2006 Annual Meeting.

Range may not be a troubling issue, since 31–39 percent of annual miles driven are the "first 20 miles" of daily driving.[18] Therefore, the daily needs of many drivers would be satisfied with this range.

PHEVs would also save a great deal of fuel. One estimate found that while a conventional vehicle uses 523 gallons per year and a HEV uses 378, a PHEV with a 20 mile range would use 219. And a PHEV with a 60 mile range would use a miniscule 83 gallons annually.[19]

There are other advantages to PHEVs. They don't suffer from the chicken-and-egg problems that plague biofuels and hydrogen, since an electrical grid already exists.[20] If charged at homes at night, they would make use of surplus, off-peak electricity. And so long as the grid is powered by relatively clean fuels—such as natural gas, hydroelectric, wind or solar—air pollution would also be reduced.[21]

- Transit Use: In urban areas, providing alternatives to driving is another viable tool for curbing oil use. According to the American Public Transportation Association, public transportation now saves us almost 125,000 barrels of oil a day. But if we increased reliance on public transportation to, say, the level of our neighbors in Canada, we would save more oil than we import from Saudi Arabia every six months.

Conclusion

Breaking our addiction, as the President called it, is a tremendous challenge. The costs to our security, our economy and our environment are terribly high. We meet this threat head-on, with similar determination that drove us to win World War II and to put a man on the Moon.

Fortunately we don't have to invent the key to our oil-soaked shackles. The technology exists, and the costs are coming down, especially in relation to the price of fuel.

To set America free, all of the technologies described above deserve greater investment and deployment. Consumers will appreciate the choice, and cumulative effects are likely to be great. For example, envision a more efficient car—whether a conventional vehicle with off-the-shelf improvements, an HEV, or a PHEV—that is also capable of running on E85. This could yield hundreds of miles per gallon of gasoline, as some have claimed.[22]

One of the best ways to put us on the path to energy security is to enact H.R. 4409, the *"Fuel Choices for American Security Act"* sponsored by Representatives Kingston, Engel and Saxton. This bill specifies specific ends—oil savings of 2.5 million barrels per day in 2015 and five million barrels per day in 2025—and provides a host of means to achieve them. It doesn't pick winners, but gives a boost to the various technologies described above. I urge you to support it.

Thank you for your time and interest.

[18] 1997 Nationwide Personal Transportation Survey, U.S. DOT, as quoted in Plotkin, Steven, "Grid-Connected Hybrids: Another Option in the Search to Replace Gasoline," TRB 2006 Annual Meeting.

[19] Plotkin, Steven, "Grid-Connected Hybrids: Another Option in the Search to Replace Gasoline," TRB 2006 Annual Meeting.

[20] Luft, Gal, "Plug in for America: California should encourage electric cars," *San Francisco Chronicle,* May 26, 2006.

[21] Plotkin, Steven, "Grid-Connected Hybrids: Another Option in the Search to Replace Gasoline," TRB 2006 Annual Meeting.

[22] Zakaria, Fareed, "Imagine: 500 miles per gallon," *Newsweek,* March 7, 2005.

Attachment

SECURING AMERICA
Solving Our Oil Dependence Through Innovation

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THE EARTH'S BEST DEFENSE

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NATURAL RESOURCES DEFENSE COUNCIL
ISSUE PAPER: FEBRUARY 2005

ABOUT NRDC

NRDC (Natural Resources Defense Council) is a national, nonprofit organization of scientists, lawyers, and environmental specialists dedicated to protecting public health and the environment. Founded in 1970, NRDC has more than 1 million members and online activists nationwide, served from offices in New York, Washington, Los Angeles, and San Francisco. For more information, visit www.nrdc.org.

ABOUT IAGS

The Institute for the Analysis of Global Security is a nonprofit public educational organization focusing on energy security. IAGS seeks to promote public awareness to the strong impact energy dependency has on our economy and security and to the myriad of technological and policy solutions that could help us move into an era of energy independence, and increase peace, prosperity, and stability in the world. Visit us on the World Wide Web at www.iags.org.

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EXECUTIVE SUMMARY

Oil dependence has become the Achilles heel of America's economy—and national security. America consumes more than 20 million barrels of oil every day, oil that powers cars, trucks, factories, and homes. Yet we have less than 3 percent of all known oil reserves and import almost 60 percent of our oil, making us dangerously dependent on a single, precarious energy source to keep our economy moving. Defense and foreign policy experts increasingly point to our oil addiction as an "incipient national security emergency" given the alarming trends in our petroleum demand, the lack of reliable alternatives to Middle East oil, and the vulnerable nature of the oil supply chain.[1] The costs and risks of America's oil dependence will increase as the global oil market tightens and geopolitical tensions threaten to disrupt supply.

Responding to this threat, the Institute for the Analysis of Global Security (IAGS) and the Natural Resources Defense Council (NRDC) forged a new alliance to advocate for a different, safer path for America. To make us more secure and to stimulate a stronger, energy-efficient economy, we should reduce our dependence on oil and invest in domestic industries that address this vulnerability. A strong national commitment to oil savings would put American manufacturers to work building the most energy-efficient cars in the world and American farms to work growing crops for new fuels. The path to energy efficiency reflects shared priorities of independence, good jobs, freedom from terrorism, and a healthy environment. We recommend the following national commitment, which can be achieved through policy measures such as those detailed in this paper:

Congress should establish a minimum national commitment to save 2.5 million barrels of oil per day by 2015 and 10 million barrels per day by 2025.

Using available technology, we could save an average of 3.2 million barrels per day within 10 years (see *Technologically Achievable Oil Savings*). Oil savings measures should be implemented across the transportation, industrial, and residential sectors. In the transportation sector, policy measures should raise the fuel efficiency of new vehicles through tax credits for retooling auto factories and consumer purchases, and by raising standards. Motor vehicle policies should facilitate the use of fuel-efficient replacement tires and motor oil, and efficiency improvements in heavy-duty trucks. Oil saving measures such as upgrading air traffic management systems and promoting residential energy savings in homes heated by oil will also contribute to a national savings goal, as will encouraging the growth of the biofuels industry. Through efficiency gains and fuel alternatives, U.S. oil consumption could be reduced almost 40 percent by 2025.

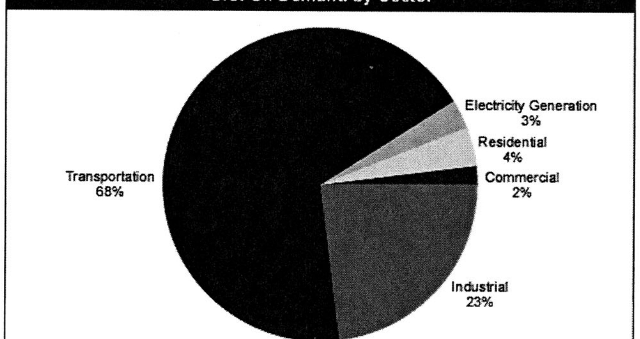
Technologically Achievable Oil Savings (million barrels per day)		
Oil Savings Measures	**2015**	**2025**
Raise fuel efficiency in new passenger vehicles through tax credits and standards	1.6	4.9
Accelerate oil savings in motor vehicles through		
fuel efficient replacement tires and motor oil	0.5	0.6
efficiency improvements in heavy-duty trucks	0.5	1.1
Accelerate oil savings in industrial, aviation, and residential sectors	0.3	0.7
Encourage growth of biofuels industry through demonstration and standards	0.3	3.9
Total Oil Saved	**3.2**	**11.2**

See Appendix for complete analyses.

AMERICA'S OIL DEPENDENCY UNDERCUTS OUR ECONOMIC STRENGTH

America's economic engine runs on oil. Oil fuels cars, trucks, factories, and homes. (see *U.S. Oil Demand by Sector*). This is especially true for the transportation sector that takes us to and from our jobs and homes; and moves goods between factories, farms, and consumers. Transportation, which forms the backbone of our economy, is also responsible for two-thirds of total U.S. oil demand. Passenger cars and light trucks alone account for nearly half of total U.S. oil consumption and consumption by the transportation sector is predicted to account for 80 percent of the surge in total U.S. petroleum demand during the next 20 years.

U.S. Oil Demand by Sector



Source: Annual Energy Outlook 2003, Energy Information Administration, Department of Energy

The cost of our oil consumption is high. Although gasoline prices hover around just $2 dollars a gallon, the real price of oil is much higher if we consider the additional expenses associated with the military costs of protecting oil transportation infrastructure, the environmental costs to our wilderness and public health, and the economic risks inextricably linked to dependence on oil. High oil prices are passed on to consumers not only through higher prices at the pump, but also through more expensive goods and services, a weaker job market, and lower stock prices.[2] In a new global market, where demand is outpacing supply and spare production capacity is dwindling, at least in the short term, the United States should expect oil prices of $40 per barrel or more.[3]

In 2004 alone, Americans spent roughly $270 billion to feed our oil appetite and oil imports accounted for roughly one-quarter of the trade deficit.[4,5] This deficit increased by 24 percent last year, which some analysts predict will upset stocks and increase interest rates.[6] The total economic penalty of our oil dependence, including loss of jobs, output, and tax revenue is estimated to be $297 to $305 billion annually.[7] During the next 25 years, the United States will likely also have to shoulder a substantial portion of the $3 trillion in global investment necessary to finance additional oil production capacity.[8]

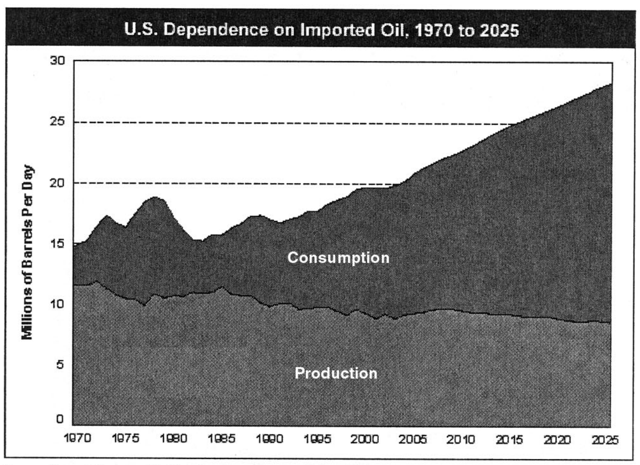
In addition to sustained high prices, a tight marketplace makes for a greater probability of price spikes in response to fears of supply disruptions because of terrorism or other causes. Oil price spikes, according to economist Philip Verleger, have cumulatively sapped 15 percent of our economy's growth resulting in $1.2 trillion in direct losses.[9] While some have argued that our economy is less effected by oil shocks than it was 30 years ago due to lower petroleum intensity—the amount of oil used per unit of GDP—America's economy is still highly vulnerable because of our high levels of imports, the global nature of the oil markets, and interdependence of today's worldwide economies.[10]

AMERICA'S OIL DEPENDENCY THREATENS OUR NATIONAL SECURITY

Defense and foreign policy experts increasingly point to America's oil addiction as an "incipient national security emergency."[11] Factors contributing to this security crisis include an alarming increase in global oil demand, America's heavy reliance on oil imports from the Middle East, the lack of reliable import alternatives, and an oil transport infrastructure vulnerable to supply disruptions.

American and global demand for oil rising faster than supply.

America's oil consumption continues to grow at breakneck speed. According to the Energy Information Administration's (EIA) 2004 Energy Outlook, the United States is projected to consume 40 percent more oil in 2025 than we do today, or 28.3 million barrels of oil per day.[12] Production capacity in the United States would only supply 30 percent of this total demand (see *U.S. Dependence on Imported Oil*).



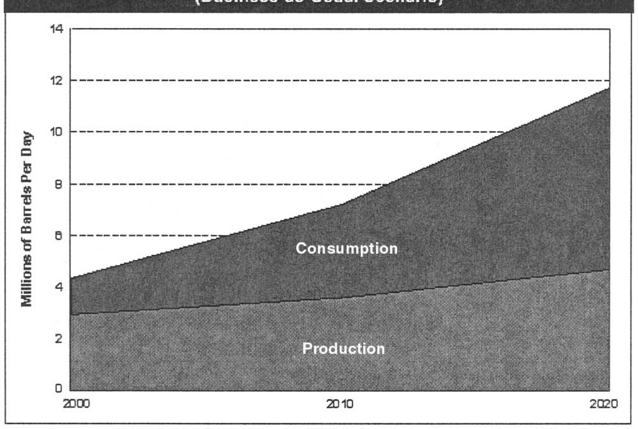
Source: Energy Information Administration, *Annual Energy Outlook 2004*

Some argue that America should open its wild lands for oil exploration and drilling to reduce U.S. dependence on imported oil. But this is a shortsighted, wasteful approach to relieving our oil dependency. Although drilling advocates claim there is potentially 16 billion barrels of technically recoverable oil in the Arctic National Wildlife Refuge, this figure is for oil recovered regardless of extraction costs. When considering the price of oil on which current production decisions are being made, about $30 per barrel, the actual amount of oil that is economically extractable is about 5.9 billion barrels.[13] Moreover, it would take 10 years for any oil from the Arctic Refuge to reach the market. Even during the predicted production peak in 2027, the coastal plain would produce less than 3 percent of America's daily oil demand.

The world now consumes oil faster than it can discover new oil reserves. In fact, the world uses about 12 billion more barrels per year than it finds.[14] OPEC is quickly exhausting excess production capacity, allowing for little relief of demand. And Saudi Arabia's efforts to cushion the market have largely failed as global capacity utilization remains at 99 percent in 2005.[15] Demand for oil in industrialized and industrializing nations is growing steeply, making the global oil market increasingly competitive. To meet projected world demand of nearly 121 million barrels a day in 2025, global oil output would have to expand by an astonishing 44 million barrels per day or 57 percent between 2002 and 2025.[16] As supply tightens, U.S. demand will continue to drive up the cost of oil in the global market.

One country's oil demand in particular is growing at an alarming pace: China. Although per capita petroleum consumption in China is just 6 percent of U.S. consumption, rapid industrialization and a growing consumer culture mean China's demand for oil is projected to grow rapidly (see *China's Dependence on Imported Oil*). Although China became a net oil importer just 10 years ago, it now imports half of its daily oil demand and in the first half of 2004 its growth accounted for roughly one-third of the increase in global oil consumption.[17]

China's Dependence on Imported Oil, 2000 to 2020 (Business-as-Usual Scenario)



Source: Development Research Center, The State Council, *China's National Energy Strategy and Policy 2000–2020*, November 2003

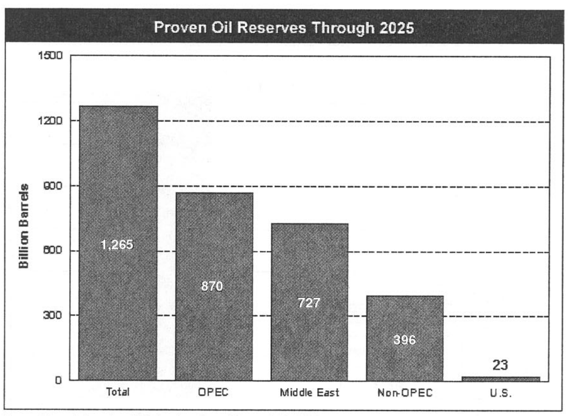
To supply its growing demand, China has begun scouring the globe (most notably in Canada, Venezuela, Russia, Africa, Kazakhstan, Saudi Arabia, and Iran) for oil supplies. It is moving quickly to secure exclusive access to future supplies by financing strategically located pipelines, expanding its oil companies, and contracting with the key oil-producing regions around the globe.[18, 19] More recently, Venezuela elected to limit U.S. production investments in favor of China.[20] Increasingly, China and the United States are in direct competition to secure control of the dwindling supply of untapped reserves. However, even China recognizes that increased fuel efficiency is a necessary part of any future energy policy and, in 2004, took an important step towards reducing demand by setting vehicle fuel economy standards more stringent than those in the United States.[21]

Another sign of an increasingly competitive global oil market is the proposed creation of an "Organization for Oil Importing Countries" between China, India, Japan, and South Korea, which would negotiate as a block for adequate supply and low prices for Asian countries.[22] In short, intensifying competition for a limited supply of oil will boost prices and increase the potential for conflict between nations addicted to this limited resource.

America is increasingly dependent on oil from the Middle East.

The third millennium marked the first time the United States imported more than half of its oil supply. If this continues, the United States will find itself importing nearly three-quarters of its oil in just 20 years. The Middle Eastern OPEC states already supply the United States with 2.5 million barrels per day—25 percent of all daily imports. So where will America's oil come from in the future?

Two-thirds of the world's proven oil reserves are located in Middle Eastern countries, including Saudi Arabia, Iran, Iraq, the United Arab Emirates, Kuwait, and Libya (see *Proven Oil Reserves Through 2025*).



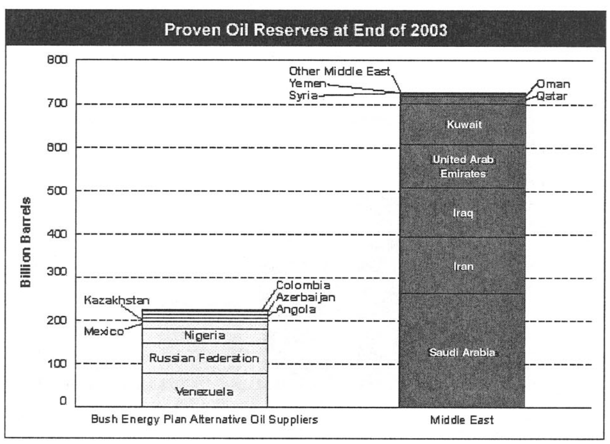
Source: Energy Information Administration, *Annual Energy Outlook* 2004

Alarmingly, the Department of Energy predicts that oil imports from the Persian Gulf to North America will double from 2001 to 2025.[23] And the International Energy Agency predicts that the global market share of production in OPEC countries, particularly in the Middle East, will soar from 37 percent in 2002 to 53 percent in 2030—slightly above its 1973 historical peak.[24]

Alternatives to Middle East oil are limited and potentially unstable.

Looking beyond the Middle East to meet U.S. oil demand offers little comfort. In May 2001, the Bush administration released its National Energy Policy. In it, the administration proposed avoiding Middle East oil dependence by targeting alternative oil-supplying nations for government investment and closer alliances, including Angola, Azerbaijan, Colombia, Kazakhstan, Mexico, Nigeria, Russia, and Venezuela.

Unfortunately, increasing imports from states outside the Middle East is a risky, short-term solution at best. The total projected reserves of these alternative oil suppliers are 198 billion barrels—70 percent lower than reserves in the Middle East. More importantly, the average reserve to production ratio of these alternative oil suppliers is just 18 years. In comparison, the Middle East has almost 100 years of proven reserves at current production levels. By depleting reserves outside the Middle East, we are creating a more severe dependence on imports from the Middle East in the future. As a former Energy Secretary put it recently, "We should not deceive ourselves, as long as we are dependent on oil to the degree that we are, that there is a substitute for the Middle East [as a source for oil]...Over time, non-OPEC oil will be depleted and we will become more dependent on oil from the Middle East."[25] Additionally, all of the nations on the administration's list face significant political and social instability and remain porous to global terrorism, making it difficult to attract the foreign investments necessary to finance future production.[26]



Source: British Petroleum, *Statistical Review of World Energy 2004*
http://www.bp.com/genericarticle.do?categoryId=111&contentId=2004175

Oil transport infrastructure is a target for those who wish America harm.

Thousands of miles of pipelines and hundreds of facilities operate like a global circulatory system to move the world's oil supply. But the system is vulnerable. According to the Institute for the Analysis of Global Security (IAGS), this supply system has multiple chokepoints critical to free-flowing oil commerce. Sixty percent of the world's oil is transported by sea via 3500 tankers annually. Every day 26 million barrels of oil flow through two chokepoints, the Straits of Hormuz in the Persian Gulf and the Straits of Malacca in Asia.[27] In the next decades, we can expect oil transportation through these channels to more than double, increasing the vulnerability of the system as well as the security costs to oil-dependent nations.[28]

America's enemies know the oil is the Achilles heel of the developed world and that the oil transportation system is vulnerable. After a suicide boat attack on the French tanker Limburg in October 2002, al-Qaeda issued a statement saying that "by hitting the oil tanker in Yemen the Mujahadeen hit the secret line—the provision line—and the feeding to the artery of the life of the Crusader nation."[29] As IAGS and others have documented, jihadists are intent on targeting oil.[30] A recent IAGS brief quoted a jihad web site that urges "brothers in the battlefields to direct some of their great efforts towards the oil wells and pipeline."[31]

Since the middle of 2003, more than 200 attacks were carried out against oil pipelines, installations, and personnel in Iraq.[32] Thousands more miles of pipelines traversing sparsely inhabited areas of the Middle East are vulnerable to attack.[33] A few targeted strikes against oil facilities in Saudi Arabia, which holds one-quarter of the world's oil reserves and essentially all spare capacity, could take several million barrels of Saudi oil off the global market every day for months and send oil prices soaring to more than $100 per barrel.[34]

Estimates suggest that during peacetime the United States spends an additional $20 to $40 billion per year in military costs to secure access to foreign oil supplies. This means that prior to the current military operations in the Middle East, the American taxpayer was already paying at least an additional $4 to $5 above market price per barrel of oil.[35] Domestic pipelines such as the 880-mile Trans-Alaska Pipeline System (TAPS) are also difficult to defend. Experts have said that TAPS is "largely accessible to attackers, but often irreparable in winter. If key pumping stations or facilities at either end were disabled, at least the above-ground half of 9 million barrels of hot oil could congeal in one winter week into the world's biggest ChapStick®..."[36]

Oil demand may be fueling terrorism.

Many oil-producing countries suffer from corruption and poor governance. Transparency International noted in its Global Corruption report that, "corruption, sustained by skewed standards of living and a lack of transparent governance across the Middle East and North Africa, is a major hindrance to the region's economic development.[37] From Yemen, with a per capita income of around US$300 a year, to the United Arab Emirates (UAE), with a per capita income of around US$18,000, all countries are confronted by nepotism, favoritism, and profiteering." The problem extends to oil producers outside the region as well.

Nigeria, for example, has received over $300 billion in oil revenue over the past 25 years, yet most Nigerians live on less than $1 per day. The bipartisan National Commission on Terrorist Attacks upon the United States (9/11 Commission) found that poor economic conditions provide a context ripe for terrorist recruitment.[38]

There is ample evidence that economic conditions are not the only element of a terrorist friendly climate in the Middle East. Prodigious oil supply can undermine democracy as well. Oil riches in the developing world have been linked to centralization of state power, difficulties in developing free societies, and the funding of incitement and terrorist networks.[39] The situation has complicated U.S.-Saudi relations so much so that the commission included a specific recommendation in its report aimed at healing the relations: "The problems in the U.S.-Saudi relationship must be confronted, openly. The United States and Saudi Arabia must determine if they can build a relationship that political leaders on both sides are prepared to publicly defend – a relationship about more than oil…"[40]

As summarized in a *Foreign Affairs* article, "It is…increasingly clear that the riches from oil trickle down to those who would do harm to America and its friends. If this situation remains unchanged, the United States will find itself sending soldiers into battle again and again, adding the lives of American men and women in uniform to the already high cost of oil…."[41] Therefore, reducing U.S. oil dependence could indirectly support the development of democracy, or as one columnist wrote: "Shrink the oil revenue and [Middle Eastern countries] will have to open up their economies and their schools and liberate their women so that their people can compete. It is that simple."[42]

It is becoming clear that U.S. policy must rise to the challenge posed by such regimes. As President Bush summarized at a recent press conference in Europe, "The policy in the past used to be, let's just accept tyranny, for the sake of - well, you know, cheap oil, or whatever it may be, and just hope everything would be okay…Well, that changed on September the 11th for our nation. Everything wasn't okay. Beneath what appeared to be a placid surface lurked an ideology based upon hatred."

ACHIEVING NATIONAL OIL SAVINGS OF 2.5 MILLION BARRELS PER DAY BY 2015

Saving oil is a matter of national commitment. Technologies exist today that can reduce wasteful use of oil in vehicles, industry, aviation, and buildings, delivering savings of at least 3.2 million barrels per day by 2015—more oil than we currently import from the Middle East each day. And by 2025, the United States could save at least 11.2 million barrels of oil per day (mbd), cutting our demand in half. We can reach these goals while enhancing competitiveness of U.S. automakers and farmers by combining new efficiency standards with tax incentives to give new life to our factories and farms. Smart energy policies can reduce America's dependence on oil, stimulate our domestic economy, and help keep our nation safe.

We recommend the following actions:

Establish a minimal national commitment to save 2.5 million barrels per day by 2015 and 10 million barrels per day by 2025.

Saving oil requires mobilizing American ingenuity, factories, and farms around a clear goal. The first, most critical, step is for Congress to establish a national commitment to cut oil expenses and reinvest the resources—otherwise sent to oil producing countries—in American factories and farms. If the past is an indicator of success for such a commitment, this savings goal is achievable. During World War II, American factories converted in just months from building cars to building tankers and bombers that became the arsenal of democracy. And after the first oil crisis in the early 1970s, America cut its oil demand to keep our economy strong. Although some may doubt the ability to turn this ship around, history shows us that American efficiency and ingenuity can meet the challenge. Saving 2.5 mbd by 2015 and 10 mbd by 2025 is well within our technical potential.

We recommend the following policy measures to achieve the oil savings:

Accelerate oil savings in passenger vehicles by:

- **establishing tax credits for manufacturers to retool existing factories so they can build fuel-efficient vehicles and engineer advanced technologies, and for consumers to purchase the next generation of fuel-efficient vehicles; and**
- **raising federal fuel economy standards for cars and light trucks in regular steps.**

As oil prices have risen, so has the demand for fuel-efficient cars and trucks, especially hybrids. Unfortunately, the "Big 3" automakers, General Motors, Ford Motor Company, and DaimlerChrysler, have been slow to get into the hybrid market. As a result, they are losing the race for clean and efficient vehicles, putting thousands of U.S. jobs at risk. A recent study by the University of Michigan found that unless U.S.

automakers move faster to build hybrids, thousands of jobs could be lost.[43] And with business as usual, the Big 3 will face a significant competitive disadvantage in the global auto market over the next few decades.[44] Putting American innovation to work can reverse this course, saving jobs while saving oil.

Tax credits for factories, consumers. Producing fuel-efficient, advanced technology vehicles will require automakers and their suppliers to retool their factories. Hybrid vehicles rely on advanced equipment such as battery packs, electric motors and generators, and electronic power controllers. Advanced diesel drivetrains require sophisticated fuel injection systems, turbochargers and advanced pollution control devices (to meet emission standards). Factories in Japan and Europe currently supply these components to the United States. Tax credits help expand market demand for these vehicles, aid manufacturers in making capital investments necessary to retool their factories, make advanced technologies more cost-effective, and stimulate job growth in the production of cleaner, more efficient vehicles.

We endorse the proposals offered by a bipartisan group, the National Commission on Energy Policy (NCEP), which recommended a total of $3 billion over the next five to ten years in consumer and manufacturer tax credits.[45] These tax credits will not only help reduce oil dependence but also will pay for themselves through increased tax revenue from new economic activity, including new jobs in the production of high-efficiency vehicles.

Fuel economy standards. The NCEP also recommended that to ensure public benefits from these tax credits, federal fuel economy standards should be raised to ensure that the increased production of the most fuel-efficient vehicles translates into national oil savings. Fuel economy standards were highly effective in cutting oil use in the late 1970s and the 1980s. According to a 2002 report from the National Academy of Sciences, Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards, the CAFE standards enacted in 1975 were a key factor in the dramatic rise of car and light-truck fuel economy between 1975 and 1988.[46] Fuel economy for new passenger cars nearly doubled, rising from 15.8 mpg in 1975 to a peak of 28.6 in 1988.[47] Fuel economy for new light trucks increased 50 percent, rising from 13.7 mpg in 1975 to 21.6 mpg in 1987.[48]

Although total fuel use by passenger vehicles has risen by 30 percent since the federal fuel economy standards were enacted, the majority of this increase took place after the fuel economy standards leveled in the mid- and late 1980s. Adding to the growth in fuel use was the rise in sales of light trucks (such as SUVs, minivans, and pickups) for general passenger use. The increase in fuel consumption would have been even greater if fuel economy standards had not been in place.[49]

Accelerate oil savings in motor vehicles through the following:

- **requiring replacement tires and motor oil to be at least as fuel efficient as original equipment tires and motor oil;**
- **requiring efficiency improvements in heavy-duty trucks; and**
- **supporting smart growth and better transportation choices.**

Replacement tires and motor oil. We should adopt a program that ensures replacement tires are as fuel-efficient as original equipment tires. The program should follow the approach already being implemented in California, by developing tire efficiency and labeling standards (based on rolling resistance) that will enable consumers to purchase the most efficient models. This measure would achieve an overall decrease in gasoline consumption by all U.S. vehicles of approximately 3 percent.

Automakers already equip new cars with low rolling resistance, fuel-efficient tires in order to comply with federal fuel-economy standards. Rolling resistance is the measure of the amount of energy needed to move a tire, so the higher the rolling resistance, the more gas the car consumes. There are no efficiency standards or efficiency labels for replacement tires, so most consumers unknowingly buy high rolling resistance tires to replace originals. A set of four low rolling resistance tires would cost consumers just $5 to $12 more than conventional replacement tires, but the average driver would recoup the additional expense of tires in fuel savings in less than one year.[50] The efficient tires would save the typical driver $50 to $150 over the 50,000-mile life of the tires.[51]

A program similar to the tire replacement program should be implemented to encourage the use of fuel-efficient motor oils. Like replacement tires, more efficient motor oil can provide fuel savings from on road passenger cars and light trucks. According to the U.S. Department of Energy, the use of specifically formulated low-friction motor oil can increase a vehicle's fuel economy by 1 to 2 percent.[52] A producer of synthetic motor oil has projected that fuel economy benefits could be as much as 5 percent.[53]

Heavy-duty trucks. We should establish standards for the smallest and largest heavy trucks. The smallest of the heavy trucks, those from 8,500 to 10,000 pounds can be improved with the same technology systems applied to other light-duty trucks. Improvements could be achieved by expanding the upper weight limit of the light-duty fuel economy standard from 8,500 to 10,000 pounds, which would bring the smallest heavy trucks into federal fuel economy program.

Improving the fuel economy of heavy-duty trucks offers a major opportunity for oil savings. Today, vehicles ranging from 8,500 pounds to more than 33,000 pounds consume the equivalent of more than 2.8 million barrels of oil each day.[54] More than two-thirds of this energy is consumed by the heaviest trucks, such as tractor-trailers weighing more than 33,000 pounds. Lighter, shorter range trucks use the remaining third of trucking fuel energy. All truck classes can benefit from fuel-efficiency gains from current and emerging technology. Technology assessments by the American Council for an Energy-Efficient Economy

(ACEEE) found that truck fuel-efficiency advances up to 70 percent are cost-effective. The heaviest long-range trucks can increase fuel economy through conventional technology improvements, including enhancements to aerodynamics, reduction of rolling resistance using tires, improved engine fuel injection and thermal management, and reductions in vehicle weight.

Although medium, short-haul trucks can also benefit from conventional technology improvements, large fuel economy advances can best be achieved through hybrid gasoline-electric or diesel-electric drivetrains. Approximately 47 percent of the mileage covered by medium trucks is in urban stop-and-go traffic where hybrid designs offer significant fuel savings by shutting down combustion engines and driving short distances on electric motors.[55]

A wide range of technologies also exists to reduce the tremendous amount of fuel used during idling. Long-haul truckers travel the highways for days. During their rest stops, drivers commonly idle their diesel engines to warm or air condition their sleeping cab, to run electrical appliances and to keep their truck's engine block warm during cold weather. Large diesel engines are designed to move heavy loads, not run auxiliary systems. More efficient technologies are available to perform the needed idling functions. Auxiliary power units sip diesel fuel compared with engine idling and, in many cases, the idling services can be performed by electrical hookups and other non-petroleum-fueled systems.

Smart growth and better transportation choices. Saving oil is one more reason to pursue smart-growth as an alternative to suburban sprawl and to expand Americans' transportation options. Federal strategies to support smart growth and better transportation choices save oil by reducing the total amount we are required to drive when we commute or run errands. The potential for smart growth oil savings is immense. If all new construction were built in a similar fashion to existing smart growth developments, the nation would save over half a million barrels of oil per day after 10 years of construction.

Congress can overcome barriers to smart growth in several ways. First, it should direct federal agencies to revise their planning models so that they account for smart growth. Currently, when new highway projects or new transit projects are evaluated economically, they rely on models that all but ignore the influence of smart growth development. Upgraded models will save money in directing investment toward more cost-effective transit and highway projects and away from ones that do not justify their cost. Enhanced models can also be used in clean air planning and in the evaluation of transit service levels.

One barrier to smart growth is that many homes located in efficient neighborhoods cost more, and the lending system treats such additional costs as barriers to affordability. The Location Efficient Mortgage® solves these problems by allowing potential borrowers with low transportation costs to apply the savings to qualification for a mortgage. Congress could require agencies like Freddie Mac and Fannie Mae to offer Location Efficient Mortgages® throughout the country in a way that allows dollar-for-dollar tradeoffs between lower transportation costs and higher housing costs.

We should promote commuter choice with a tax-free benefit for employees who car-pool, use transit, bike to work, or telecommute (currently limited to $100 per month) equal to that provided in the form of free parking (which is at about $200 and is pegged to inflation). This can have a big effect: One recent study in Minneapolis-St. Paul found that more than one in 10 employees shifted from driving to some other way of commuting when offered tax-free commuter benefits equal to those provided in the form of free parking.[56]

We should also support cutting the red tape and streamlining financing for public transportation projects that significantly increase mobility of public-transportation-dependent populations and promote economic development in urban "transit-oriented development zones." Projects to evaluate road user charges, which would make the portion that a driver pays for highway maintenance costs depend on how much a person uses the roads, are also worthy of support. This system of recovering costs, currently being researched by several experts, would ensure continued revenue to the highway trust fund.[57]

Accelerate oil savings in industrial, aviation, and residential building sectors through the following:

- **expanding industrial efficiency programs to focus on oil use reduction and adopting standards for petroleum heating;**
- **replacing chemical feedstocks with bioproducts through research and development and government procurement of bioproducts;**
- **upgrading air traffic management systems so aircraft follow the most-efficient routes; and**
- **promoting residential energy savings with a focus on oil-heat.**

Approximately one-third of U.S. oil demand is consumed in industrial manufacturing plants, airplanes, and residential homes. Efficiency gains in these sectors can save America more than 300,000 barrels per day in 2015 or 12 percent of the 2.5 millions barrels per day national target.

Industrial process heating efficiency. The industrial sector includes manufacturers of diverse products including steel, cement, food, plastics, glass, paper, and chemicals. Heating fuel oil, diesel fuel, and liquefied petroleum gas are used by manufacturing companies for firing boilers and heating and reheating materials during the manufacturing process. Improving the efficiency of boilers and process heating can reduce oil consumption by 15 percent by 2020. We should expand industrial efficiency programs to focus on oil use reduction and adopt standards for petroleum heating efficiency and incentives to accelerate old, inefficient equipment.

Bioproducts. Also in the industrial sector, using petroleum as a feedstock for chemicals and manufactured materials consumes four times the amount of oil used for heating. Oil savings can be achieved by substituting petroleum-based feedstocks with materials derived from crops, or biomass. Today, biomass is used in the production of solvents, pharmaceuticals, adhesives, resins, detergents, inks, paints, lubricants and plastics. According the U.S. Department of Energy (DOE), bio-feedstocks could displace 13 percent of petroleum-based feedstocks by 2020.[58] Continued funding of biomass research and development efforts and on-going requirements for government procurement of environmentally sustainable bioproducts will spur the production of substitutes to petrochemical feedstocks. In 2015, oil saving in the production of industrial chemicals could add up to 120,000 barrels per day.

Air traffic management. Airlines use less jet fuel when they use the most direct traffic patterns and minimize idling time before and after landing. Advanced air traffic management technologies available today for aviation communications, navigation, and surveillance (CNS) systems improve airline fuel efficiency by enabling planes to take more direct routes (such as more great circle routes) between destinations, use more airspace at currently prohibited lower elevations, and minimize time waiting for landing and take-off strips. Improvements to CNS systems allow aviation control to migrate from ground-based, limited-range systems to less-constrained satellite-based systems.

According to the U.S. DOE, CNS improvements can reduce commercial jet fuel consumption by 5 percent by 2020.[59] CNS upgrades minimize aircraft rerouting (when conditions unexpectedly change in the air or at airports), control take-off and landing spacing and enable after-flight aircraft and routing performance analysis. We should fund advancements to the air traffic management system that increase routing efficiency and therefore reduce per-passenger fuel consumption.

Oil-heated homes. Petroleum products remain an important source of heating energy in homes. According to the EIA, approximately 8 million residences continue to burn fuel oil, liquefied petroleum gases (LPG), propane, and kerosene for space and water heating. [60] Cost-effective home improvements to space and water heating systems such as insulating walls, ceilings and pipes, sealing drafts and especially sealing ducts, installing new windows, upgrading thermostats; updating furnaces; replacing old clothes washers and dishwashers with new efficient models; and replacing water heaters can reduce heating oil use by 30 percent or more.

We should promote residential energy savings with a focus on oil heat to help reduce the nation's oil dependence by adopting stringent efficiency standards for house and apartment building boilers and furnaces; by adopting performance-based tax incentives for home retrofits and for efficient water heaters; and by updating codes for new buildings. Together these measures can save 100,000 barrel of oil per day in 2015. We should promote residential weatherization and other energy saving programs to help achieve the national oil savings commitment.

Encourage growth of the biofuels industry through the following:

- **requiring all new cars and trucks to be capable of operating on biofuels or other non-petroleum fuels by 2015;**
- **converting the federal oxygenate requirement, which is not necessary to meet clean air goals, to a renewable fuel standard; and**
- **allocating $2 billion in federal funding over the next 10 years to help the cellulosic biofuels industry expand production capacity to 1 billion gallons per year and become self-sufficient by 2015.**

Although fuel efficiency is critical to immediately reducing our oil dependence, we must also develop alternative, non-petroleum fuels that can be grown by American farmers. The biofuel feedstock with the potential to displace the largest amount of oil is cellulosic biomass, which includes agricultural residue (the leaves, stems, and stalks of plants), dedicated energy crops, and the biomass portion of the municipal waste stream. Ethanol and methanol, both alcohol fuels, can be made from cellulosic biomass.

A market for biofuels already exists. In 2004, the United States produced more than 3.4 billion gallons of ethanol, almost all from corn, for use as an additive to gasoline.[61] Because the gasoline oxygen additive methyl tertiary butyl ether (MTBE) has been found to contaminate water supplies, the chemical is being replaced by ethanol. Gasoline blended with 10 percent by volume ethanol can be used in unmodified vehicles, but it creates air pollution problems in today's on-road cars. Higher blends of these alcohol fuels, however, can be used only in vehicles specifically designed to burn high-oxygen fuel. So-called flexible-fuel vehicles (FFV) can run on gasoline blended with almost any amount of alcohol fuel. The most common high-blend fuel is 85 percent ethanol, E-85. Because high blend ethanol fuel is typically more expensive than gasoline, less than 1 percent of the FFVs on the road today burn gasoline with high ethanol content such as E-85 high blend ethanol from corn.[62] Fortunately, ethanol made from other sources, called cellulosic ethanol, promises to substantially reduce this cost.

Biofuels in new cars and trucks. We should require the use of higher-biofuel blends in gasoline. Higher ethanol blends not only displace more oil but also decrease harmful particulate air pollution associated with lower-ethanol blends in gasoline. To accomplish this, we should require all new cars and trucks to be capable of operating on biofuels or other non-petroleum fuels by 2012. To operate on E-85, and other high-ethanol and methanol blends, FFVs require low-cost technology improvements that generally make the FFV only slightly more costly to buy than its conventional, gasoline-only counterpart.

Ethanol made from cellulosic biomass offers numerous advantages, as detailed in a recent report lead by NRDC for the National Centers for Environmental Prediction (NCEP). The technology for converting cellulose to biofuels is expected to be cost-competitive with petroleum-based fuels. Cellulosic biomass crops, such as switchgrass, have the potential to produce more biomass per acre than almost any other crop and as a perennial they require lower inputs of energy, fertilizer, pesticide, and herbicide, and is accompanied by less erosion and improved soil fertility. Cellulosic biomass also contains substantial amounts of non-fermentable, energy-rich components that can be used to provide energy for the conversion process as well as to produce electricity and other fuels using non-biological conversion processes.[63] With the right policies in place, there is tremendous potential for biofuels to displace petroleum in our cars and trucks. By 2050, biofuels could contribute the equivalent of 7.9 million barrels of oil per day, or 53 percent of our current demand.[64]

Federal oxygenate requirement. To facilitate the transition to cellulosic biofuels, the federal oxygenate requirement, which is not necessary to meet clean air goals, should be converted to a renewable fuel standard. Such a system would provide much needed flexibility to areas that are suffering from the nation's worst air quality to blend effective, low cost, cleaner burning gasoline formulations. To encourage cellulosic production, credits for biofuel production should be awarded based on the environmental performance of its lifecycle including its feedstock production, processing, refining and combustion. In addition to displacing oil consumption, the EPA should be required to ensure that biofuels are used in a way that maintains or improves air quality, water quality and water supply. As the capacity for biofuels production with cost-effective and sustainable practice grows, We should increase production targets of the renewable fuels standard only if it can be demonstrated that there will be no increase in air pollution.

Biofuels funding. Two billion dollars in federal funding for biofuels over the next 10 years would spur innovation, development, and demonstration projects aimed at making biofuels cost-effective for consumers. The funding should supply incentives that will stimulate the growth of the cellulosic biofuel industry toward a production target of 1 billion gallons per year and make the industry self-sufficient by 2015. These funds should be used to achieve two major goals:

- Investing in a package of research, development, and demonstration policies that create the innovations and advances needed for a large-scale, competitive biofuels industry; and
- Funding deployment policies that drive the development of the first billion gallons of cellulosic biofuels capacity at a price approaching that of gasoline and diesel.

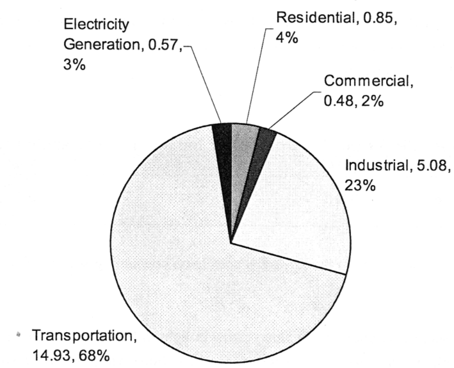
APPENDIX

METHODOLOGY TO ANALYZE OIL SAVINGS POTENTIAL

This report analyzes the potential to save oil through a combination of greater efficiency and switching to domestic, biomass-derived fuels and materials. To evaluate the potential to reduce petroleum consumption, we used stock-turnover models for various sectors. Our baseline scenario for petroleum demand is calibrated against the U.S. Energy Information Administration's *Annual Energy Outlook 2003* unless otherwise noted. [65]

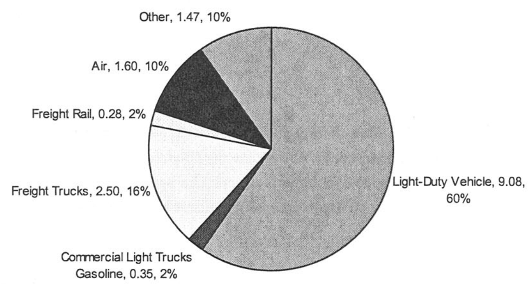
In 2003, the United States consumed nearly 20 million barrels of oil per day (mbd) in the transportation, industrial, and residential sectors. Figures 1 and 2 describe the breakdown of oil consumption across all sectors and within the transportation sector.

Figure 1: Petroleum Consumption by Sector (mbd, % of total), 2003



Source: Energy Information Administration (EIA), *Annual Energy Outlook 2003* (AEO 2003).

Figure 2: Transportation Sector Petroleum Consumption (mbd, % of total), 2003



Source: EIA AEO 2003.

Over the next 20 years, U.S. oil demand from the transportation, industrial and residential sectors is projected to grow by 45 percent to more than 29 mbd (see Table 1).[66] In 2025, these three sectors will comprise 94 percent of U.S. oil demand.

Table 1: Oil Demand Profile for the Transportation, Industrial, and Residential Sectors

	2003	2015	2025
Demand, mbd	19.46	25.14	29.35
Percent of Total U.S. Demand	89%	92%	94%
Total Growth (from 2005)		24%	45%

We assess oil savings potential across the three key petroleum consuming sectors. The key measures we examine are as follows:

- Transportation sector: we analyze efficiency gains in light-duty passenger vehicles, heavy-duty trucks (over 8,500 pounds gross vehicle weight) and aviation operations. We also consider the use of renewable fuels, primarily ethanol, to displace gasoline and diesel fuel in cars and trucks.
- Industrial sector: we calculate oil savings from boiler and process heating efficiency gains and from the substitution of biomass-derived products for petroleum as the feedstock, or key ingredient, for industrial chemicals and other manufactured materials such as plastics.
- Residential sector: we analyze oil savings from improved home space and water heating through furnace burner upgrades, wall insulation, and other measures.

The oil savings in each sector are technically achievable. We assume cost-effective technologies and practices are implemented over the next two decades starting between 2008 and 2011, depending on the oil saving measure. We chose aggressive yet attainable technology penetration rates; these rates are driven by federal programs that establish performance requirements coupled, in some cases, with incentives for consumers or producers or both.

Table 2 summarizes, in millions of barrels per day (mbd), the total savings that can be achieved from oil savings measures in the transportation, industrial, and residential sectors. Using existing technologies, the United States could reduce its demand for oil by over 3 mbd by 2015 and more than 11 mbd by 2025. The remainder of this appendix provides greater detail on the source and level of oil savings for each sector.

Table 2: Oil Savings Potential from All Sectors

	2015	2025
Oil Savings Potential (mbd)	3.15	11.17

PASSENGER VEHICLE FUEL EFFICIENCY

To ensure that the increased production of the most fuel-efficient vehicles translates into national oil savings, Congress can raise federal fuel economy standards. New legislation should ramp up the standards for the combined fleet of cars and light trucks in regular steps to as much as 40 miles per gallon (mpg) by 2015 and as much as 55 mpg by 2025.

Fuel economy standards were highly effective in cutting oil use in the late 1970s and the 1980s. According to a 2002 report from the National Academy of Sciences, *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards*, the CAFE standards enacted in 1975 were a key factor in the dramatic rise of car and light-truck fuel economy between 1975 and 1988.[67] Fuel economy for new passenger cars nearly doubled, rising from 15.8 mpg in 1975 to a peak of 28.6 in 1988.[68] Fuel economy for new light trucks increased 50 percent, rising from 13.7 mpg in 1975 to 21.6 mpg in 1987.[69]

While total fuel use by passenger vehicles has risen by 30 percent since federal fuel economy standards were enacted, the majority of this increase took place after the fuel economy standards leveled in the mid- and late 1980s. Adding to the growth in fuel use was the rise in sales of light trucks (such as SUVs, minivans, and pickups) for general passenger use. The increase in fuel consumption would have been even greater if fuel economy standards had not been in place.[70]

As shown in Table 3, oil demand from passenger vehicles is projected to become an increasing share of total U.S. demand. This growth can be offset by raising fuel economy standards for passenger vehicles. Today, new passenger cars and trucks achieve a combined fleet fuel economy of 24.4 mpg.[71] Just raising the standard to achieve a fleetwide average for new vehicles as much as 40 mpg by 2015 and as much as 55 mpg by 2025 would reduce oil consumption from passenger vehicles by more than 13 percent in 2015 and more than 34 percent in 2025.

Table 3: Passenger Vehicle Sector Profile

	2003	2015	2025
Demand, mbd	9.08	12.21	14.34
Percent of Total U.S. Demand	41%	45%	46%
Total Growth (from 2005)		28%	51%

Measure 1: Increase Fuel Efficiency of New Passenger Vehicles

The 2002 report by the National Academies of Science (NAS) and independent studies by the Union of Concerned Scientists (UCS), the American Council for an Energy-Efficient Economy (ACEEE), and the Massachusetts Institute of Technology all indicate that cars and light trucks can achieve large additional fuel savings if fuel economy standards are increased.[72,73,74] In fact, it is clear that automakers have the technology to raise fuel economy standards for new cars and light trucks to 40 mpg by 2015 and 55 mpg by 2025.

Description of Technologies

Cost-effective technologies exist today for near-term and longer-term improvements in vehicle fuel economy. Table 4 provides a short list of conventional technologies that have already been developed by automakers that could significantly increase the fuel economy of today's cars and light trucks, many of which are already in some cars.

Table 4: Conventional Technology Options for Fuel-Economy Improvement

Vehicle Load Reduction
Aerodynamic improvements
Rolling resistance improvements
Safety-enhancing mass reduction
Accessory load reduction
Efficient Engines
Variable valve control engines
Stoichiometric burn gasoline direct injection engines
Integrated Starter Generators
Improved Transmissions
Five- and six-speed automatic transmissions
Five-speed motorized gear shift transmissions
Optimized shift schedules
Continuously variable transmissions

The NAS report, which assumed more constraints on light truck weight reduction, and the USC report suggested that similar fuel economy levels could be achieved within 10 to 15 years. Both the NAS and UCS results agree that a fleet average of close to 35 mpg is technically feasible and cost effective in less than 10 years. In short, even a standard of 55 mpg by 2020 is feasible and cost-effective.

The NAS report indicates that a standard as high as 47 mpg could be achieved with further improvements to conventional gasoline-powered internal combustion vehicles. Further, ACEEE and UCS studies demonstrate that by combining these improvements in conventional vehicle technology with gasoline-electric hybrid drive systems, it is possible to reach a fleet average of 54 to 56 mpg.

Oil Savings Potential

To estimate the oil savings from these scenarios (see Table 5), we used a stock turnover model developed by the Tellus Institute for projecting transportation and other energy demands under different policy and technology scenarios. The stock model, called the Long-range Energy Alternatives Planning System, or LEAP, is calibrated to EIA's AEO 2003 to establish a baseline of energy consumption to 2025 from the light-duty fleet.

Table 5: Fuel-Efficient Vehicle Savings Potential

	2015	2025
Oil Savings Potential (mbd)	1.65	4.89

Since AEO 2003 was published, the National Highway Traffic Safety Administration (NHTSA) enacted a 1.5 mpg increase in light truck fuel economy standards from 2005 to 2007. To account for these new standards, we modified the baseline in LEAP to include the increase in fuel economy. Oil savings are calculated in LEAP using this new baseline. We assume a 40 mpg fleet wide fuel economy is achieved by 2015, and then linearly ramps up to achieve 55 mpg by 2025. We also assume a mileage 'rebound' of 10 percent due to the possibility for increased fuel economy to induce slightly more driving.

Our projections of oil savings are conservative because they are relative to an AEO 2003 baseline that assumes long-term increases in fleet fuel economy. Based on trends for the last 15 years of decreasing fleetwide fuel economy, we find it difficult to believe the EIA's forecast that fleet fuel economy will increase without increases in federal fuel economy standards. According to EPA analysis, fleet fuel economy reached its peak value in 1987-1988 and then declined into the late 1990s. Since then it has remained relatively constant.[75] AEO 2003 projects greater fleetwide fuel economy gains in years following 2015 than would be achieved by simply adding the 2005-2007 light truck CAFE standard increases.

A baseline that considers a constant fleetwide fuel economy after the light-truck CAFE increases could be used as an alternative baseline for oil demand. NRDC analyzed the oil savings scenarios in comparison to the 'flat-efficiency' baseline and found greater oil savings. For example, in a scenario where fuel economy standards require new vehicles to meet 40 mpg by 2015 and 55 mpg by 2025, oil savings in 2025 were an additional 250,000 barrels of oil per day. This is a 5 percent increase in savings as compared to the AEO 2003 baseline, which includes the 1.5 mpg light truck standard increase.

Measure 2: Adopt Fuel-Efficient Replacement Tires

Automakers equip new cars with tires that are more fuel efficient than those sold as replacement tires. Automakers do this in order to help these cars meet federal fuel-economy standards. Rolling resistance is the measure of the amount of energy needed to move a tire. Requiring replacement tires to be as fuel-efficient as the original equipment tires would improve a vehicle's fuel economy by up to 6 percent.[76]

California has just begun a program whose goal is to ensure that replacement tires, on average, are as fuel efficient as original equipment tires. This program (AB844, Nation 2003) is modeled after the highly successful home appliance energy efficiency program. The program, known as the Replacement Tire Efficiency Program, requires the California Energy Commission to test and rate passenger vehicle replacement times. By 2008, replacement tires sold in California must meet minimum fuel efficiency standards, and dealers must prominently display fuel efficiency ratings for all tires they sell.

Description of Technologies

The technology to make replacement tires is literally "off-the-shelf" since it is being used by virtually all manufacturers of original equipment tires. A common strategy for producing low rolling resistance tires is to use rubber compounds infused with silica. The silica replaces traditional carbon black materials and can be added to the tire manufacturing process at little additional cost.

Furthermore, this technology does not involve compromising any traction or tread life. Low rolling resistance tires can have excellent grip, handling, and tread wear characteristics. This is demonstrated by the organization Green Seal in a report that rates a variety of tire brands and models for rolling resistance, traction, tread wear and consumer satisfaction.[77]

Low rolling resistance tires are highly cost-effective. Consultants to the California Energy Commission (CEC) estimated the cost for a set of four low rolling resistance tires to be just $5 to $12 more than conventional replacement tires.[78] The average driver would recoup the additional expense of tires in fuel savings in less than one year. The efficient tires would save the typical driver $50 to $150 over the 50,000-mile life of the tires.[79]

Oil Savings Potential

To analyze the oil savings potential, we developed our own spreadsheet model that uses the AEO 2003 passenger vehicle fuel consumption as our baseline (see Table 6). From the baseline, we subtract the fuel used by on-road cars and light trucks riding on replacement tires (approximately 75 percent of the on-road fleet). We assume that low rolling resistance replacement tires are made to be as fuel efficient as original equipment tires and provide a 4 percent reduction in fuel consumption. This is a conservative estimate of the CEC consultant report which noted potential savings of up to 6 percent.

Table 6: Fuel-Efficient Replacement Tire Savings Potential

	2015	2025
Oil Savings Potential (mbd)	0.36	0.42

Since proven fuel-efficient tire technology already exists it can penetrate the replacement tire market rapidly. We assume that by 2014, the technology penetrates the entire market and is in use by passenger vehicles.

Measure 3: Adopt Fuel-Efficient Motor Oil

Advances in light-duty vehicle motor oil can save oil through two methods: (1) increase the fuel economy of vehicles using the advanced oil and (2) reduce the frequency of oil changes. In this analysis, we only look at the first method.

Description of Technology

Motor oils are formulated to minimize friction losses in the engine across a broad range of temperatures. Low viscosity, or thin, oils with 0W or 5W ratings are often used because they reduce engine load and save fuel. Advancements in oil technology have enabled the low viscosity oils required in low temperatures to also stand up to the stress of high temperature engine operation.

Low viscosity oils are produced from petroleum (mineral bases) and from man-made compounds (synthetics). Producers of synthetic oils claim superior engine protection performance and fuel economy but these oils are more expensive to produce. Research by the Society of Automotive Engineers demonstrates that the fuel efficiency of mineral oils can be improved so that they qualify as ultra-low viscosity oils, which have been demonstrated to reduce fuel consumption by 3 percent compared to a vehicle using a 5W-rated oil.[80]

The U.S. Department of Energy (DOE) suggests using engine oil grades recommended by the vehicle manufacturer and using oils specially formulated to achieve larger reductions in engine friction. According to the DOE, the use of fuel efficient motor oil can increase a vehicle's fuel economy by 1 to 2 percent.[81] Synthetic engine oil producer, AMSOIL, notes that fuel economy benefits could be as much as 5 percent.[82]

Synthetics offer benefits other than greater energy efficiency. Oils made from synthetics last longer than mineral oils. While automobile manufacturers recommend changing oil every 3000 miles, some synthetic oils are said to protect and lubricate engines for 35,000 miles or 1 year.[83] While drivers typically change their oil two to four times per year, switching to synthetic oil could reduce changes to one per year and lead to a large reduction in motor oil consumption.

Oil Savings Potential

To analyze the oil savings potential, we only account for oil saved from increased engine efficiency; we chose to not include the oil savings potential from longer lasting oil because current vehicle warranties require more frequent oil changes and because synthetic oils are more expensive (see Table 7).

Table 7: Fuel-Efficient Motor oil Savings Potential

	2015	2025
Oil Savings Potential (mbd)	0.12	0.14

We conservatively assume that fuel-efficient motor oil reduces fuel consumption in passenger vehicles by 1 percent. A national fuel-efficient motor oil program could set efficiency and labeling standards for motor oil so that energy-saving motor oil is widely available by 2011. Since drivers typically change their oil multiple times each year, we assume that all passenger vehicles use the advanced motor oil by the end of 2012. To prevent double-counting oil savings from different technologies applied to the same vehicle, we calculate the motor oil savings from an oil consumption baseline that has already had the savings from fuel-efficient replacement tires removed.

HEAVY-DUTY TRUCK EFFICIENCY

Heavy-duty trucks includes all trucks of gross vehicle weight of 8,500 pounds to over 33,000 pounds. Heavy trucks are the second largest consumer of oil in the transportation sector and third largest among all sectors. Within trucking, efficiency gains are made from improved fuel economy when running and from the reduction of fuel consumption during idling (see Table 8).

Table 8: Heavy-Duty Truck Sector Profile

	2003	2015	2025
Demand, mbd	2.84	3.97	4.74
Percent of Total U.S. Demand	13%	15%	15%
Total Growth (from 2005)		32%	57%

Measure 4: Raise Fuel Economy of New Heavy-Duty Trucks

Improving the fuel economy of heavy-duty trucks offers a major opportunity for oil savings. Today, the equivalent of over 2.8 million barrels of oil are consumed each day to power trucks ranging from 8,500 pounds to more than 33,000 pounds.[84] More than two-thirds of this energy is consumed by the heaviest trucks, such as tractor-trailers weighing more than 33,000 pounds. Lighter, shorter range trucks use the other one-third of trucking fuel energy. All truck classes can benefit from fuel-efficiency gains from current and emerging technology. Technology assessments by ACEEE find that truck fuel-efficiency advances of up to 70 percent are cost-effective.

Description of Technologies

Fuel-saving technology advances fall into two categories: conventional and hybrid drivetrain. Tractor-trailers and long-haul straight trucks are good candidates for conventional technology improvements including enhancements to aerodynamics, reduction of rolling resistance using tires, improved engine fuel injection and thermal management and reductions in vehicle weight.

Table 9 outlines the different cost-effective technologies and their contribution to fuel efficiency as evaluated by ACEEE. Unless otherwise noted, all technologies are available for introduction into the market by 2008. Aerodynamic improvements minimize the resistance caused by air flowing over the truck cab and trailer. Pneumatic blowing is a technology under development that reduces drag and rolling resistance by blowing streams of air under the truck. Wide-based tires are also designed to have low-rolling resistance. Electrically powered auxiliaries replace equipment that is normally driven by the mechanical power of the engine. For example, pumps, compressors and fans are energized by an electrical starter-generator or a fuel cell (beginning in 2012). Efficiency gains within the engine are achieved through low-friction lubricants, increased cylinder compression ratios, more precise fuel injection and better use of waste heat through mechanisms such as turbocharging. Vehicle mass reduction is achieved through light-weight, high-strength metals or plastics to replace heavier steel components.

Table 9: Convention Heavy Truck Technologies to Improve Fuel Economy

Technology	% Improvement in Fuel Economy
Aerodynamics	
Cab top deflector	1.5
Cab-trailer gap closing	2.5
Trailer edge curvature	1.3
Pneumatic blowing	6.0 beginning in 2012
Rolling Resistance	
Low-rolling resistance, wide-based tires	3.0
Electrical auxiliary power	
Starter-generator	1.5
Fuel cells	6.0 beginning in 2012
Engine	
Friction reduction	2.0
Increased peak cylinder pressure	4.0
Improved fuel injection	6.0
Turbocharging and other thermal management	5.0; Additional 5.0 beginning in 2012
Vehicle mass reduction	7.5 beginning in 2012

While medium trucks can also benefit from conventional technology improvements, large fuel economy advances can best be achieved through hybrid gasoline-electric or diesel-electric drivetrains. Approximately 47 percent of the mileage covered by medium trucks is in urban stop-and-go traffic where hybrid designs offer significant fuel savings by shutting down combustion engines and driving short distances on electric motors.[85]

Oil Savings Potential

Oil savings estimates are based on fuel-efficiency gains for each truck type as new technologies are introduced into the heavy-duty fleet (see Table 10). Stock turnover models for each truck class from the EIA's National Energy Modeling System (NEMS) are used to calculate annual oil savings.[86]

Table 10: Fuel-Efficient Heavy-Duty Truck Savings Potential

	2015	2025
Oil Savings Potential (mbd)	0.38	1.00

Table 11 summarizes the assumptions used in the model and the resulting oil savings for 2015 and 2025. The fuel-efficiency increases for each truck type are based on technical assessments by ACEEE for a report to the National Commission on Energy Policy.[87] Advances in fuel economy before 2008 are assumed to be zero although existing technologies are gradually being integrated into the truck fleet. From 2008 and beyond, technology penetrates new trucks rapidly to achieve the fuel efficiency gains shown in the table. For trucks more than 10,000 pounds we assume that fuel efficiency gains are achieved in 10 years, and for the smallest trucks (8,500 to 10,000 pounds) we assume that gains are reached by 2015. The small truck trajectory is consistent with the rate assumed in light-duty trucks since the technology and primary manufacturers are the same.

Table 11: Heavy-Duty Truck Efficiency Gains and Oil Savings

Truck Type	Fuel Efficiency Gain	Oil Savings (mbd)	
		2015	2025
Long-haul tractor-trailers (Class 8, 33,000 lbs and up)	61%	0.25	0.71

Conventional technology			
Long-haul straight trucks (Class 7&8, 26,000 lbs and up) Conventional technology	55%	0.01	0.04
Local trucks (Class 3-8, 10,000 lbs and up) Hybrid drivetrain technology	70%	0.03	0.07
Small commercial trucks and large SUVs, vans and pickups (Class 2b: 8,500 – 10,000 lbs) Conventional technology	66%	0.09	0.18

Fuel efficiency gains in tractor trailers deliver the bulk of oil savings from heavy-duty trucks. New fuel efficiency standards for heavy trucks over 26,000 pounds encourage technologies to be implemented into the new truck stock over ten years resulting in fuel economy gains of 61 percent in long-haul tractor trailers and 55 percent in long-haul straight trucks. Total long haul oil savings reach 260,000 barrels in 2015 and 750,000 barrels in 2025.

The introduction of hybrid technology into locally-driven trucks can raise fuel economy by 70 percent or more. Hybrid drive trains are already being designed for some delivery trucks, and with expanded research and development funding these drivetrains can be quickly expanded to other local truck platforms. Tax incentives can also lower the risk to manufacturers of producing trucks with more expensive hybrid technology. The potential oil savings from using hybrid drivetrains in trucks more than 10,000 pounds is 30,000 barrels per day in 2015 and 70,000 in 2025.

The lightest of the heavy-duty trucks, class 2b trucks ranging from 8,500 to 10,000 pounds, use more than 350,000 barrels of gasoline per day. The introduction of fuel-saving technologies similar to those available to light-duty vehicles can reduce oil usage by more than 90,000 barrels per day by 2015, a reduction of 18 percent from projected oil use in this class. Currently, class 2b trucks are not regulated under the CAFE system for light-duty passenger vehicles, but over half of the trucks in this class are used as personal vehicles.[88] Analysis by ACEEE found no significant technical barriers to expanding CAFE to include trucks up to 10,000 pounds.[89] Class 2b trucks can benefit from much of the same fuel-saving technology designed for lighter trucks and can fit into the existing fuel economy and emissions testing programs.

Measure 5: Reduce Heavy Duty Truck Idling

Currently, approximately 2.8 million heavy trucks travel U.S. highways to deliver their freight. The heaviest trucks, those with a gross weight of more than 26,000 pounds, are often traveling long distances that require the drivers to rest. During their rest stops, drivers commonly idle their diesel engines to warm or air condition their sleeping cab, to run electrical appliances, and to keep their truck's engine block warm during cold weather. In many cases, however, the functions performed by engine idling can be replaced by other technologies that do not run on petroleum fuel. Therefore, introducing these technologies can reduce the diesel fuel consumption by heavy trucks and provide significant oil savings.

Description of Technologies

Technologies to displace diesel engine idling and provide truck heating and cooling include (1) direct-fired heaters (heating only), (2) thermal storage systems, (3) auxiliary power units (APU), and (4) truck stop electrification. Both the direct-fired heaters and APUs burn petroleum, but they operate much more efficiently than the diesel engine for supplying services to the engine and cab (the direct-fired heater is approximately 80 percent efficient for heat delivery compared to only 11-15 percent for truck idling).[90] Thermal storage systems provide only cab heating and cooling services by storing heat energy in a phase-changing material when the engine is operating. Truck stop electrification allows the truck to be plugged into the local electrical grid to receive energy services. It requires special configurations in the truck and development of the truck stop infrastructure. Some companies have already begun providing this service for truckers. For example, IdleAire Technologies Corporation has installed systems in 10 states, providing heat and television and Internet connections for drivers.[91]

Oil Savings Potential

Only those heavy trucks (over 26,000 pounds) that travel over 500 miles per day, or 18 percent of on-road heavy trucks, are considered eligible for the technology (see Table 12). We assume that diesel-powered APUs with an efficiency of 82 percent (as compared to truck engine idling) penetrate the market over a four year period reaching 100 percent of eligible truck stock by 2012.

Table 12: Heavy-Duty Idling Reduction Savings Potential

	2015	2025
Oil Savings Potential (mbd)	0.07	0.08

Efficiency standards for idling equipment along with purchase incentives to drive market demand can ensure rapid reductions in diesel fuel use when heavy trucks are off the road.

INDUSTRY

Measure 6: Improve Industrial Efficiency

The industrial sector includes manufacturers of diverse products including steel, cement, food, plastics, glass, paper and chemicals (see Table 13). Heating fuel oil, diesel fuel, and liquefied petroleum gas are used by manufacturing companies for firing boilers and heating and reheating materials during the manufacturing process. Improving the efficiency of boilers and process heating provides modest but significant reductions in U.S. oil consumption.

Table 13: Industrial Sector Profile

	2003	2015	2025
Demand, mbd	5.08	5.83	6.55
Percent of Total U.S. Demand	23%	21%	21%
Total Growth (from 2005)		11%	25%

Description of Technologies

Better practices and new technologies can significantly raise boiler and furnace fuel efficiency and reduce material heating and reheating requirements. According to the DOE many existing boiler and heating systems exhaust as much or more heat energy than goes into heating the manufactured materials.[92] To reduce waste heat losses, the DOE recommends that industries (1) ensure that boilers and heating enclosures are properly insulated to minimize wall losses and air infiltration, (2) properly tune burners to optimize the fuel-air ratio, (3) carefully schedule material loading rates and amounts to operate heating systems at designed capacity, and (4) closely align materials entering the heating process with those that are exiting the system so that waste heat can be used to preheat the incoming materials.

Additional equipment can also improve process heating efficiency. Direct heat exchangers capture waste heat from boiler stacks and preheat materials before they enter the boiler. Gas-to-gas heat exchangers, called recuperators, reduce fuel usage by preheating incoming combustion air with heat from stack gases. Regenerators also capture waste heat; however, they store the thermal energy in metal or ceramic blocks and discharge it to materials during process heating. Upgrading boilers and furnaces with advanced burners and combustion controls also improves fuel efficiency.

Oil Savings Potential

The oil savings potential of the industrial sector is based on ACEEE's analysis of EIA's 1998 Manufacturing Energy Consumption Survey (MECS) and the EIA 2004 *Annual Energy Outlook*. The MECS quantifies the breakdown of petroleum use among boiler and furnace fuel, process fuel and other non-process use, such as on-site transportation (see Table 14). It is assumed that the end-use breakdown from the MECS remains constant through 2025. The growth in petroleum demand is determined from the *Annual Energy Outlook.*

Table 14: Industrial Process Efficiency Savings Potential

	2015	2025
Oil Savings Potential (mbd)	0.04	0.09

Oil savings estimates are developed for boiler fuel and process heating. ACEEE estimates that oil consumption reductions in boilers of 19 percent by 2020 are technically achievable. Reductions of total process petroleum use are estimated at 15 percent by 2020. Assuming that no savings are achievable in non-process industrial oil use, the weighted average of savings from industrial efficiency gains (across boiler, process and non-process uses) is 14.6 percent in 2020. Year-by-year reductions are calculated by assuming linear ramp up in savings from 2009 to the 2020 value and then continuing improvements at the same rate to 2025.

Efficiency standards for boilers, furnaces and other heating processes, programs to institute industrial heating best practices and incentives to retire old, inefficient equipment are instrumental in driving improved industrial efficiency.

Measure 7: Substitute Bio-Feedstocks for Petrochemical Feedstocks

In the industrial sector, four times more oil is used as the feedstock for chemicals and manufactured materials than for heating. Oil savings would result from substituting petroleum-based feedstocks with materials derived from crops, or biomass. Today, biomass replaces petroleum feedstocks in solvents, pharmaceuticals, adhesives, resins, detergents, inks, paints, lubricants and plastics.

Description of Technologies

Two principle conversion technologies, biochemical and thermochemical, are used to convert biomass into industrial chemicals and bio-based products. Biochemical technologies use enzymes or microorganisms to ferment the starch and sugars in grains such as corn. Thermochemical technologies use an acid or metal or combined catalyst in high temperature and pressure processes to convert biomass. Table 15 lists the technologies used for each category of biomass and the resulting products from biomass conversion.

Table 15: Current Industrial Bioproduct Production from Domestic Biomass

Category	Principal Technologies	Feedstock	Chemical	General Product	Annual Biobased Production (M lb)
Starch and Sugars*	Biochemical	Biomass sugars derived from corn and sorghum	Lactic acid, citric acid, ethanol, starch, sorbitol, levulinic acid, itaconic acid	Polymers, solvents, cleaners, coatings, inks, detergents, pharmaceuticals, adhesives, paints, composites, laminates, toiletries, cosmetics	5,413
Oil/Lipids	Thermochemical	Oils/lipids derived from soybean, rapeseed	Glycerol/glycerine, alkyd resins, high erucic acid rapeseed, polyurethane, epoxidized soybean oil, factice, sulfurized fatty oils, fatty acids, cyclopentadienized oils, lecithin, maleinized oils	Pharmaceuticals, personal care, urethanes, alkyd resins, plasticizers, lubricants, paints, resins, printing inks, industrial and textile finishes, semi-rigid foam, thermoplastic elastomers, cosmetics, coatings, surfactants, sealants, caulks, pesticides	1,589
Specialty Crops	Thermochemical	Spearmint, peppermint, sweet almond	Spearmint oil, peppermint oil, sweet almond oil	Personal care, pharmaceuticals, epoxy and alkyd resins, paints, cosmetics, and toiletries	9
Forest Derivatives	Thermochemical	Pine, black liquor, soft wood	Turpentine oil, rosin, tall oil, and cellulose derivatives (esters, acetates, etc.)	Solvents, soaps, detergents, toiletries, perfumes, rubber, adhesives, coatings, printing inks, phenolic resins, plastics, textiles	5,326
Total					12,337

*The ethanol and citric acid included here are for industrial use only (e.g., solvent, cleaning reagent).
Source: Paster, Mark, Joan L. Pellegrino, and Tracy M. Carole, *Industrial Bioproducts: Today and Tomorrow*, Prepared by Energetics, Incorporated for the U.S Department of Energy, Office of Energy Efficiency and Renewable Energy, Office of the Biomass Program, Washington, DC, July 2003, p. 37.

The growth of bioproducts is dependent on advancements in several technology areas. Cellulase enzymes are being developed to more cost effectively break down cellulosic biomass. Unlike petroleum feedstocks, the availability of biomass feedstocks is dependent on weather, water, soil and pest conditions. Sustainable agricultural advancements such as conservation tillage, integrated pest management and sophisticated irrigation techniques are important to the economics of bioproducts and provide opportunities to expand industrial use of biomass.

Oil Savings Potential

According to the DOE, petro-chemical feedstocks reductions of 13 percent by 2020 are technically achievable.[93] Assuming the DOE estimate, we developed year-by-year reductions using a linear ramp up in savings from 2009 to the 2020 value and then continuing improvements at the same rate to 2025 (see Table 16).

Table 16: Oil Savings from Industrial Bio-feedstock Substitution

	2015	2025
Oil Savings Potential (mbd)	0.11	0.26

Renewable content standards and labeling enable consumers to differentiate products made from biomass. Requirements on government agencies to purchase chemicals and materials with significant biomass content will drive technically achievable reductions in oil use.

AVIATION

Table 17: Aviation Sector Profile

	2003	2015	2025
Demand, mbd	1.60	2.24	2.86
Percent of Total U.S. Demand	7%	8%	9%
Total Growth (from 2005)		37%	75%

Measure 8: Improve Air Traffic Management

When airplanes fly the most direct routes and spend less time idling before takeoff and after landing, less jet fuel is used. Improved aviation fuel efficiency can result in petroleum savings of over 140,000 million barrels per day in 2025. In 1998, the Federal Aviation Administration (FAA) began its Free Flight Program (http://ffp1.faa.gov/) to implement technologies that streamline flight planning and ground logistics.

Description of Technologies

Air traffic management (ATM) technology advances cut across aviation communications, navigation and surveillance (CNS) systems. So-called CNS/ATM programs enable planes to take more direct routes (such as more great circle routes) between destinations, use more airspace at currently prohibited lower elevations, and minimize time waiting for landing and take-off strips. CNS/ATM improvements establish a network of ground- and satellite-based systems to more precisely track airplane locations and movement and allow for more efficient routing and rerouting (when conditions unexpectedly change in the air or at airports), take-off and landing spacing and after-flight performance analysis.[94]

Oil Savings Potential

According to the U.S. Department of Energy, CNS/ATM efforts can deliver 5 percent reductions in fuel use by 2020.[95] With new CNS/ATM technology introductions, the FAA has set an even more ambiguous goal of "improving aviation fuel efficiency per revenue plane-mile by 1 percent per year through 2009, as measured by a three-year moving average, from the three-year average for calendar year 2000-2002."[96]

For our oil savings potential analysis (see Table 18), we assume the DOE estimate of 5 percent reduction in jet fuel usage by 2020. Efficiency savings ramp up from zero to 5 percent from 2008 to 2020 and then remain constant at 5 percent through 2025.

Table 18: Air Traffic Management Savings Potential

	2015	2025
Oil Savings Potential (mbd)	0.07	0.14

RESIDENTIAL

Measure 9: Improve Efficiency of Oil-Heated Homes

Petroleum products remain an important source of heating energy in homes. According to the EIA, approximately 8 million residences continue to burn fuel oil, liquefied petroleum gases (LPG) such as propane and kerosene for space and water heating.[97] Petroleum residential heating products are expected grow slightly over the next decade but become a smaller share of total U.S. oil consumption as oil use in other sectors experience higher growth rates (see Table 19). Efficiency gains in residential oil use can counter any growth and lead to overall decreases in annual oil consumption from the sector.

Table 19: Residential Sector Profile

	2003	2015	2025
Demand, mbd	0.85	0.90	0.86
Percent of Total U.S. Demand	4%	3%	3%
Total Growth (from 2005)		0%	-4%

Description of Technologies

ACEEE analyzed cost-effective efficiency improvements to homes that will save fuel energy for space heating and water heating. Home improvements such as insulating walls and ceilings, sealing spaces where air can infiltrate from the outside, installing new windows, sealing heating ductwork, and upgrading thermostats to better control heaters all contribute to improved efficiency. Heater and furnace efficiency can be improved through burner replacement or a heating system upgrade. Water heating efficiency is improved with pipe insulation, low-flow faucets and shower heads, and low-water use clothes washers.

Potential Oil Savings

The potential oil savings are determined by multiplying the percentage gain in efficiency from the measures above to a baseline of residential petroleum use from the EIA's 2001 Residential Energy Consumption Survey (see Table 20).[98] The reduction in fuel use from each efficiency measure is determined from existing home energy efficiency studies.[99] We recognize that homeowners may choose to implement only a subset of the efficiency measures based on the condition of their home, so the savings from each measure are multiplied by an estimate of the number of eligible homes and a percentage of participation by homeowners.

Table 20: Residential Efficiency Savings Potential

	2015	2025
Oil Savings Potential (mbd)	0.09	0.23

The final savings numbers are considered the oil savings achieved in 2020. We assume that oil savings linearly ramp up from 2009 through 2025; this was calculated by a simple extrapolation of the 2020 savings. As noted above, the savings are developed from a 2001 baseline. Since residential heating oil use projected by AEO 2003 is expected to grow very slowly and then flatten out, using the 2001 baseline creates a conservative savings estimate.

The oil savings are categorized by policy mechanisms to encourage the efficiency improvements. These categories include (a) efficiency standards for oil and LPG boilers and furnaces, (b) building codes for new homes built after 2009, and (c) home retrofit programs for single-family and multi-family dwellings. The savings from the implementation of efficiency standards for new boilers and furnaces ranges from 5 to 11 percent. Updated building codes for new homes deliver savings of 15 to 30 percent. Home retrofit programs are intended for homes built before 2001; their participation rate and savings potential are a function of how much the program is expanded.

We assume that increased efficiency standards and new home building codes are set at the Energy Star level, representing a 30 percent savings from current building codes; apartment and home retrofit programs are maximized through low-cost or zero-interest loans and technical assistance; and savings of 30 percent are realized for the 90 percent of eligible homes that participate in the program.

RENEWABLE FUELS

Measure 10: Increase the Use of Renewable Fuels

While raising vehicle fuel economy will make the largest contribution to reducing U.S. oil consumption over the next two decades, it is also essential to begin moving beyond oil as the primary energy source for our vehicles. The biofuel that has the potential to reduce the largest amount of oil is ethanol derived from cellulosic materials, rather than today's dominant source in the United States: corn.

There is a market for ethanol already. In 2004, the U.S. produced over 3.4 billion gallons of ethanol almost all from corn and used as an additive to gasoline.[100] Since the gasoline oxygen additive MTBE has been found to contaminate water supplies, the chemical is being replaced by ethanol. Gasoline blended with 10 percent by volume ethanol can be used in unmodified vehicles, but it creates air pollution problems in today's on-road cars. Higher blends of ethanol can be used only in vehicles specifically designed to burn the high-oxygen fuel. So-called flexible-fuel vehicles (FFV) can run on gasoline with no ethanol or fuels with nearly 100 percent ethanol by volume. The most common high-blend fuel is 85 percent ethanol, known as E-85. However, because high blend ethanol fuel is typically more expensive than gasoline, less than 1 percent of the FFVs on the road today burn gasoline with high ethanol content like E-85 in high blend ethanol from corn.[101]

Description of Technologies

Today, almost all ethanol produced in the United States is made from corn grown specifically for making the fuel. Ethanol is produced by fermenting the sugars in the corn. Ethanol derived from cellulosic biomass has the potential to make biofuels a cost-effective petroleum replacement within a decade. The feedstock for cellulosic ethanol is the woody biomass from crops that has little food value. Cellulosic ethanol is produced from existing agricultural waste (such as corn stover and rice straw) and municipal waste (such as yard waste and food scraps) and from fast-growing energy crops (such as switchgrass, poplars and willows). Using waste products and energy crops as feedstock can drastically lower the production costs of the fuel.

Cellulosic ethanol also has environmental benefits. The net energy content (energy input during ethanol production subtracted from ethanol fuel energy) of cellulosic ethanol is approximately three times that of corn ethanol.[102] Greenhouse gas emissions are also minimized when using cellulosic feedstocks. According to a study by Argonne National Laboratory, on a per vehicle mile basis greenhouse gas emissions are reduced 1-2 percent when using corn-based ethanol in E10 and 24-26 percent in E85. Cellulosic ethanol achieves reductions of 8-10 percent in E-10 and 68-91 percent in E-85.[103]

However, the production of cellulosic ethanol is more complicated and expensive than fermenting the sugars in corn. The cellulose has to be first broken down into fermentable sugars, and the methods of cellulose decomposition are currently not economic on a commercial scale. A recent study lead by NRDC for the National Commission on Energy Policy (NCEP) describes a program for bringing cellulosic biofuels to the market. We use the recommendations of the NCEP project in our estimates of petroleum substitution by biomass ethanol.

Oil Savings Potential

Oil savings over the next two decades come from both the growing of the corn-based ethanol supply and the development and growth of cellulosic ethanol supplies (see Table 21). We assume that corn-based ethanol production reaches a five billion gallon per year capacity by 2007 and then remains constant. Cellulosic ethanol reaches 1 billion gallon annual capacity by 2015 through aggressive research, development, and deployment policies.

Table 21: Renewable Fuels Savings Potential

	2015	2025
Oil Savings Potential (mbd)	0.28	3.92

A spreadsheet model is used to calculate the oil savings from the combined contributions of corn and cellulosic ethanol through 2025. Cellulosic ethanol production capacity reaches 1 billion gallons in 2015 and then grows at an annual rate of 60 percent with a maximum added capacity of 10.8 billion gallons from one year to the next. The growth rate is consistent with maximum growth rate seen in the corn ethanol industry. The additional capacity cap is based on the highest capacity addition made by the refining industry weighted by GDP.

The long-term goal of biofuel use is to entirely displace gasoline and diesel use in vehicles and other motor equipment. As biofuel supplies expand beyond their current levels, their use should be focused on high-blend applications. This is especially important with ethanol. Widespread use of low blends of ethanol (with 10 percent or less ethanol in gasoline) has been shown to harm air quality in metropolitan areas already struggling to meet federal standards for pollutants such as oxides of nitrogen and ozone. High blend applications (such as E-85 in FFVs) avoid these air quality challenges and promote the infrastructure needed to support greater biofuel distribution.

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BIOGRAPHY FOR DERON LOVAAS

Deron Lovaas is Vehicles Campaign Director at the NRDC. He currently directs the "Break the Chain" oil security campaign and was the chief lobbyist on the federal *Transportation Equity Act for the 21st Century* (TEA–21) reauthorization bill. A graduate of the University of Virginia, he has worked in the field of environmental policy and advocacy for more than a decade, in positions such as director of Sierra Club's Challenge to Sprawl campaign and specialist in transportation and air-quality planning at Maryland's Department of the Environment. He has authored or co-authored numerous articles and publications, most recently "Taking the High Road to Energy Security" in *In Business* magazine, "From Gas Crisis to Cure" on *tompaine.com* and NRDC's "Securing America: Solving Oil Dependence Through Innovation."

Chairwoman BIGGERT. Thank you very much, Mr. Lovaas.

Mr. Gott, you're recognized for five minutes.

STATEMENT OF PHILIP G. GOTT, DIRECTOR FOR AUTOMOTIVE CUSTOM SOLUTIONS, GLOBAL INSIGHT, INC.

Mr. GOTT. Thank you, Chairman Biggert, Mr. Honda, Mr. Lipinski and others Members of the Subcommittee.

What would be required to lead automakers to apply technology advancements to improving fuel economy? The automotive industry will respond to increased demands for fuel economy from the consumer: Changes in consumer behavior that place a higher priority on fuel economy will result in the increased deployment of presently available technology such as hybrids, down size and turbo charged gasoline engines, displacement on demand, et cetera. A clear regulatory position on the future of emission standards beyond tier two will enable manufacturers to make an assessment of the likely future prospects for regulatory acceptance of the diesel, the one technology that meets all consumer expectations for performance while delivering a 20 to 30 percent improvement in fuel economy.

Changes in consumer behavior can be expected if and when the need for fuel consumption reduction better resonates with the core values of the consumers. The bulk of today's car buying public places high priority on the need for economic, physical and social survival. With current fuel prices and availability, fuel consumption on a lower priority than other vehicle attributes such as a high seating position which increases aerodynamic drag, faster acceleration which usually results in a engine that operates at off peak efficiency most of the time, and high perceived levels of mobility and safety that result in vehicles heavier than might normally be necessary.

Policies in the United States have lacked from the very beginning any component that attempts to change consumer behavior. Emphasis has been placed instead on maintaining mobility and lifestyle in a business as usual consumer environment. What is needed is a series of coordinated efforts all aimed at conservation. Programs that sponsor the development of high risk technologies need to be continued simultaneously with public education programs that increase public awareness of the need to conserve and to make it in their best interests to do so.

It is likely that the high risk technologies will have some limitations or will change to some extent the normal expectations of today's vehicles with respect to range, refueling, convenience or performance. The core values of future consumer generations can be influenced by including in the education of current school age children the need to conserve in all forms so that they embrace the new technologies and their differences from vehicles of today.

Education programs need to be re-enforced with fiscal programs that are in alignment with conservation goals. Programs. Programs that tax excessive consumption and reward conservation for new vehicles as well as those in use will provide additional incentives to conserve.

What hurdles must hybrids, FlexFuel and hydrogen powered vehicles clear before the automobile industry analysts and the press accept these technologies and consumers buy them? Without a change in consumer values, transparency is the primary condition that must be met for the consumer to adopt a new technology in today's marketplace. Cost, reliability, durability, range, refuel time and convenience all need to be equal or better than the technology we seek to replace. Hybrids suffer from higher costs, both initial and life cycle as their fuel economy is generally insufficient to give a payback, at least with today's fuel prices, to the original purchaser during the first ownership period, and battery life issues cloud the resale value.

Hydrogen vehicles present a host of range, refueling and access challenges in addition to the technical issues and uncertainty of a net benefit when well to wheel issues are considered.

Of these three technologies mentioned, Flex-fuel vehicles offer the one technologically transparent solution but only because ethanol-containing fuel is not required to run them. To make a difference in energy consumption, the six million FFVs produced to date must have accessed the E85 at competitive costs. At the moment there are less than 700 E85 stations nationwide versus 175,000 refueling sites for conventional fuels.

How more or less likely is it that these radically new technologies, fuel cells, electric drive trains or significant battery storage capabilities, for example, will be incorporated into cars rather than incremental innovations to internal combustion engines? Historically radical technologies like these have not been incorporated into the vehicle fleet primarily because they are not transparent to the consumer when assessed on the basis of one or more of their criteria of cost, utility or convenience. Incremental changes and innovations have been the experience; evolution rather than revolution. This will be changed by the marketplace if and when they can meet the expectations of the core values of the consumers. Concurrent achievement of competitive cost, initial and/or life cycle, range, refueling time, all weather performance, well to wheel efficiency and greening house gas emissions remain significant challenges. Demonstration and other education programs can help consumers understand the benefits and the trade offs. Because it appears likely that these technologies will be accompanied by changes in these characteristics, the likelihood that these technologies can be incorporated into cars can be increased by also working through public education programs to influence the formation of core values of future generations, thus changing the willingness of the consumer to accept the changes.

In sum, regardless of how the end results are achieved, we forecast that increases in efficiency of the vehicles through available nondistruptive power train technologies will reach the point of diminishing returns once an improvement of approximately 30 percent has been achieved when compared to the baseline gasoline engine. In the absence of radical new technologies to obtain improvements greater than this will require the use of either alternative fuels or a move by the consumer to inherently more efficient and lighter vehciles.

Thank you very much.

[The prepared statement of Mr. Gott follows:]

PREPARED STATEMENT OF PHILIP G. GOTT

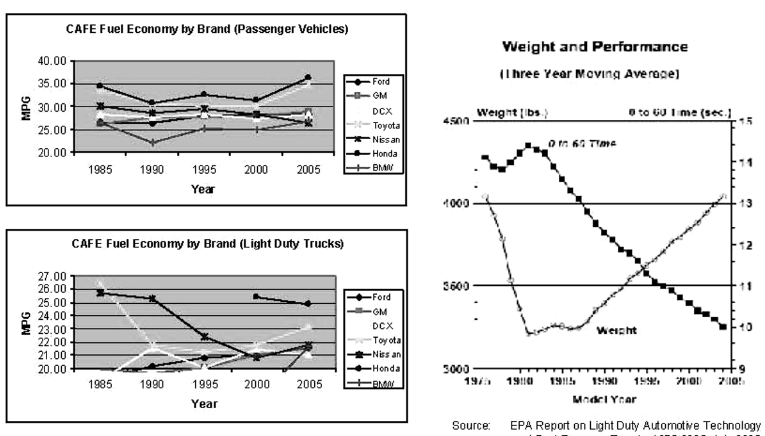
The following are the written answers to two questions posed by the Honorable Judy Biggert, Chairman, Subcommittee on Energy of the Committee on Science.

Question 1:

The auto industry in recent years has generally used technological improvements to increase performance instead of fuel efficiency. What would be required to lead automakers to apply technology advancements to improving fuel economy?

Commercially successful manufacturers design, develop, build and sell vehicles that resonate with the core values of the consumer and that meet the needs of their life stage in the current and expected future business and economic environment. The automakers will design, develop, produce and sell whatever vehicles the consumer will buy. Advanced technologies have been applied to date to hold the CAFE performance of the U.S. light vehicle fleet at or close to regulatory levels while providing increased acceleration, levels of safety and interior feature content. If large numbers of consumers were to demand instead, or in addition, greater levels of fuel economy, the manufacturers would be able to respond with a broader range of hybrids, diesels, downsized and turbocharged gasoline engines, displacement on demand, etc. At this point in time, however, it is our view that while fuel economy is increasingly important to many consumers, most still place a higher priority on other vehicle features and attributes. If and when fuel economy becomes a higher priority for the consumer, the vehicle manufacturers can and will respond.

Trends in CAFÉ, Acceleration Performance and Vehicle Weight.



Source: EPA Report on Light Duty Automotive Technology and Fuel Economy Trends: 1975-2005, July 2005

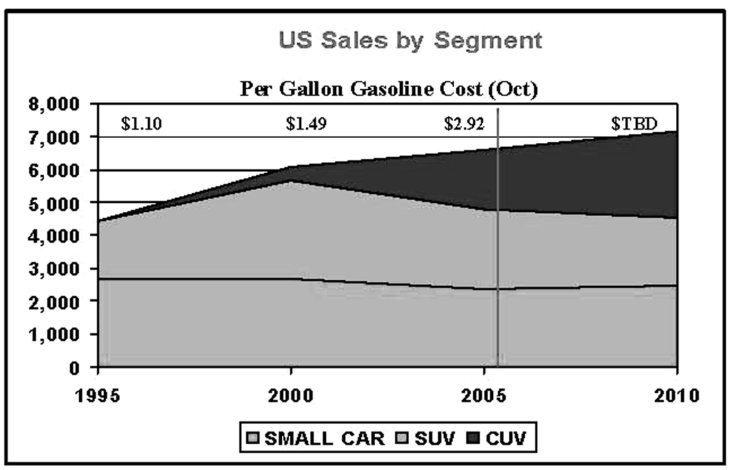
What will increase the consumer's demand for fuel economy?

Demand for fuel-saving technologies will increase when fuel conservation creates a greater resonance with the consumer's core values. Our research indicates that the Baby Boomers, the bulk of today's new car buying public, have core values that center around the need for economic, physical and social survival. They have an inherent need to prepare themselves to deal with any and all foreseeable adversities.

The need for mobility itself is a key aspect of survival, and viewed as an unalienable right by virtually all Americans. The need to travel in perceived security under any adverse driving conditions gives rise to demand for four wheel drive. The need to command and control their driving environment gives rise to demand for a high seating position. The need to be better than the next person gives rise to demand for fast accelerating vehicles. The desire for perceived safety gives rise to demand for massive vehicles. Hence the demand for large, truck-based SUVs.

However, fuel prices are currently very high, at least when compared to historical levels. For the moment, the high fuel costs have not been assimilated into the family budgets of most consumers, and demand is shifting to vehicles with attributes similar to the SUV, but on more fuel efficient front-wheel drive-based passenger car platforms (so-called "crossover utility vehicles" or "CUVs"). (It is interesting to note that small car sales are NOT increasing at the same time due to their lack of appeal to the core values of the consumer.) This momentum towards more efficient vehicles could be sustained if consumers cannot adjust to higher gasoline prices. It is our view, that if prices stay at these current levels and don't go higher, some of the momentum will diminish and consumers will go back to older buying patterns.

U.S. Sales of SUVs, CUVs and Small Cars
(thousands of units)



Source: Global Insight, Inc.

It must be recognized that the consumer has so far had an amazing capability, over the longer-term, to assimilate high fuel prices into the family budget. On the policy side, artificially high fuel prices due to taxation have not been acceptable due to the repressive nature of such taxation and the negative impact on the popularity amongst the voters of those who support them. (In this area, Americans are unique compared to consumers in many other major consuming countries.) Therefore, we need to find other, lasting solutions. Let's take a look at some of the consumer core values and how they can be reached by advanced technologies.

The Baby Boomer consumer, as part of his/her value for survival, has a strong competitive ethic embodied in the need to be better than the next person. Hybrids, which do not provide a financial payback due to their inherently high cost and sensitivity to duty-cycles, are being re-engineered to return some fuel economy benefits while also offering high levels of acceleration. The diesel engine, which offers much higher levels of acceleration-producing torque as well as fuel economy when compared to a gasoline engine, can offer equal if not better acceleration than a gasoline hybrid while more reliably providing the fuel economy benefits desired by society.

Acceleration Times of Various Hybrids Compared to Their Base Vehicle

0-60 MPH times (seconds)			
Model	Base	Hybrid	Result
Honda Civic	9.5	11.3	Neg
Honda Accord	7.9	7.4	Pos
Ford Escape	9.1	9.4	Neg
Lexus RX	7.8	7.3	Pos
Lexus GS	5.7	5.2	Pos
Toyota Highlander	7.6	7.3	Pos
07 Toyota Camry	6.7	7.0 est.	Neg

Various sources

"It's very important to continue pursuing substantial reductions in fuel consumption and emissions, while continuing to improve performance and driving pleasure. Our customers wouldn't have it any other way" said Lexus Vice President of Marketing Mark Templin. The result is a level of acceleration performance similar to a V-8 engine

The need for survival also causes a person to seek a safe and secure environment. Conventional wisdom supports the notion that a safe vehicle is a heavy vehicle. Parents who want to ensure the safety of their children prefer to carry them around in a heavy vehicle such as an SUV. There is a current Country and Western song that even states "I'm not going to sacrifice the safety of my family just to save a gallon of gas." The relationship between safe and heavy needs to be discredited before one can expect a large shift away from heavy vehicles.

Another aspect of survival is to ensure the safety and security of one's self and one's children. This includes preparation of a safe and secure future. A fact-based public education program about the need to conserve all forms of energy, including but not limited to the energy consumed for mobility, would be expected to increase demand for fuel-saving technologies. Education programs have been successful in reducing smoking, seat belt utilization and reductions in drunk driving. Why not similar programs in the schools, on television and other media in support of energy conservation?

Successful education programs can include:

- Fact-based propositions as to the net benefits to the individuals and society
- Fact-based education as to the full costs of less efficient practices and preferences
- Model behavior by role models, including movie stars, pop idols, politicians, corporate fleets
- "Placement" of strategic messages within popular culture and media: TV, movies, newspapers, etc.
- Requirements for obvious energy saving measures in all aspects of life can provide a constant reinforcement of the need to conserve in everything we do. In Europe and China, the lights in hotel hallways are off unless the presence of a person is detected. When you walk down the hall, the lights follow you, turning on ahead of you and turning off a few minutes after you pass. In America, lights burn brightly, often 24 hours per day.
- Classroom instruction during the formative childhood years.

Each of these channels of influence should work to embed the message that the core value of "survival" in adverse conditions (whatever they may be) is enhanced through energy-conserving solutions. That is, the core value of survival needs to encompass reduced dependency on a single source of energy. Survival also needs to be linked to minimization of greenhouse gases just as people came to accept the need to reduce toxic and smog-forming emissions in the 1960s.

Such educational programs should be enhanced with feebate and registration-tax programs. Under a feebate program, fees on less fuel-efficient programs would be used to subsidize the purchase of more fuel efficient vehicles in a manner similar to what is done now in some states to reward safe drivers with a discount on insurance, the discount being funded by higher rates for unsafe drivers. Recurring carbon- or fuel-consumption based registration or "circulation" taxes, paid every year by the car owner, based on the fuel consumption rating of the vehicle, can also encourage the purchase of more fuel efficient new as well as used cars. Education programs coupled with cost savings through government managed stick and carrot programs can be effective.

Another way to reach the core values of the consumer is to change the perception of mobility itself. It will be futile to try to reduce the consumer demand for mobility.

A successful strategy could be instead to offer virtual mobility as an alternative. High speed communications provided through fiber optic networks into every home will reduce the waiting time for Internet-based communications exchanges. Telecommuting and video conferencing can become an even more viable alternative to physical commuting and shopping with higher upload and download speeds. Perhaps even a system of rewarding corporations (as opposed to the individual) for establishing satellite offices or encouraging "working from home" would go a long way to reducing fuel consumption. What is required is to make the consumer realize that this is a convenient and effective alternative form of mobility.

Question 2a:

What hurdles must hybrids, flex-fuel, and hydrogen-powered vehicles clear before the automobile industry, industry analysts, and the automotive press accept these technologies and consumers buy them?

The primary caveat associated with the adoption of any new technology is that any negative attributes should be totally transparent to the consumer. That is, there should be:

- *No cost penalty over the life of the vehicle*
- *No reliability/durability penalty*
- *No range penalty*
- *No functional penalty*
- *No convenience penalty.*

Flex-fuel (FFV) vehicles have been accepted by the public for many years, and they are cost competitive and 'transparent' to the consumer in all aspects except range when fueled with the lower energy content E85. Since 1995, over six million have been produced and sold in North America. The incremental cost for their production is very small, and is largely associated with the use of a low-cost sensor and selection of fuel and intake system materials that are compatible with the fuel. The incentive has primarily been the CAFE credit given the vehicle manufacturer for selling such vehicles.

Production of FFVs by Major U.S. Vehicle Manufacturers
1995 - 2005

Year	DCX	FORD	GM	Annual Total	Cum. Total
1995	346	85,158	131,095	216,599	216,599
1996	794	122,468	138,471	261,733	478,332
1997	28,923	146,504	126,799	302,226	780,558
1998	163,120	234,102	187,625	584,847	1,365,405
1999	208,248	264,720	185,956	658,924	2,024,329
2000	185,782	257,470	188,131	634,063	2,658,392
2001	320,172	294,812	89,916	704,900	3,363,292
2002	314,267	294,984	248,861	858,112	4,221,404
2003	202,980	255,044	282,873	740,897	4,962,301
2004	103,638	217,117	244,437	565,192	5,527,493
2005	124,367	205,770	146,415	476,552	6,004,045

Source: Global Insight Powertrain Database

In order for these FFV vehicles to make a difference in our national petroleum demand, the ethanol-based fuel E85 must be more widely available at a cost competitive with that of gasoline.

There is less energy per gallon of ethanol than gasoline or diesel, so the cost must be adjusted to give the consumer a cost-per-mile that is equal or less than gasoline in order to gain widespread acceptance of the fuel. It is well-known within the government that of the approximately 175,000 refueling stations in the U.S., there are only 4,992 alternative fuels stations reported by DOE, and of those, only 637 offer E85.[1]

Hydrogen has greater challenges than FFV, although some are similar in nature. Ford and BMW have demonstrated that it is possible to offer hydrogen powered vehicles today, burning the fuel in an internal combustion engine. However, hydrogen fuel requires new fuel production, distribution and vehicle fueling systems. In addition, as hydrogen is currently understood, it would require some changes in consumer behavior to operate. On-board storage issues result in reduced range and some restrictions on the access of these vehicles to all public places. In addition to these challenges, the major hurdle to creating demand for them is the almost total lack of a hydrogen refueling infrastructure.

Technologically, there are a number of challenges to the production, distribution and storage of hydrogen so that there is a net benefit to society. Briefly stated, they are:

- **Production:** By most methods, the production and compression of hydrogen will create more greenhouse gas and use more energy than is saved by burning it in an engine. The theoretically high efficiencies of the fuel cell are needed to make a net gain possible with hydrogen fuel. Achievement of these high efficiencies at commercially viable cost levels is one of the major goals of fuel cell developers.
- **Distribution:** Hydrogen is the smallest natural molecule known to man. It can therefore leak out of the smallest holes, even finding its way through the very small crevices and cracks that exist in many metals and joints that contain other liquids and larger gas molecules very well. The cost and technical challenges of setting up a distribution system that can hold such a molecule has led many to consider the deployment of decentralized refueling stations that generate hydrogen on-site. These are not cheap either, and without any vehicles on the road to use the fuel, there is no incentive to make the investment. The classic chicken-and-egg dilemma.
- **Storage:** The energy density of hydrogen is very low. To give a vehicle a competitive range (distance between refueling stops) it is necessary to store it at very high pressures or other means of densification. Development of cost-effective tanks to provide such storage is underway, but making certain that they are safe in all foreseeable accidents is a major challenge. Also, most parking garages and many bridges prohibit vehicles with compressed flammable gases. The access of vehicles fueled by hydrogen and other gasses to these structures needs to be addressed before full acceptance of these vehicles can be expected.
- **Refueling practices** associated with the various alternatives being explored for on-board storage would likely be different and more complex than those currently accepted for gasoline and diesel fuel. Standards for refueling systems and associated safe practices will need to be developed. With the current level of consumer expectations for self-service gasoline or diesel, refueling with hydrogen is likely to be anything but transparent to the consumer.

Increasing emphasis should be placed on the solutions to these challenges: low-impact production of hydrogen, creation of a hydrogen refueling infrastructure and solving the on-board fuel storage and refueling challenges. If these issues are addressed and the manufacturers incented to produce, and the consumer incented to buy, hydrogen-fueled vehicles using internal combustion engine technology, a fueling infrastructure will evolve that will cause basic market forces to bring more efficient fuel cell technologies to market when their major hurdles have been overcome.

Hybrids are transparent to the consumer and offer significant fuel savings to a limited number of vehicle owner/drivers. There are three major "rules" that govern where hybrids can offer financial payback to those who buy them:

1. **The duty cycle must be highly transient.** In other words, there must be a lot of stop and start to really maximize the savings of the hybrid powertrain. Hybrids work by capturing energy normally expended in the brakes and recycling it to assist the engine as it accelerates the vehicle. If there is very little opportunity for energy capture, there is very little opportunity for energy savings with the hybrid.

[1] *http://www.eere.energy.gov/afdc/infrastructure/station_counts.html*

2. **Fuel use must be high.** That is, the distance traveled in a year must be large so that there exists an opportunity for financial payback.
3. **An opportunity should exist to offset high brake maintenance** costs with the hybrid, adding to the financial incentives to adopt the technology.

For most consumers, fuel prices will have to be much higher before there is payback for the extra cost of the hybrid technology. Indeed, it is generally accepted that hybrids present a poor financial case for the average consumer.[2] As the cost of batteries declines with advances in technology and market volumes, we expect that this payback period will be reduced. However, used vehicle residual values due to questions about battery condition and the still high cost of mature replacement batteries (we estimate about $1,500 based on discussions with battery chemists) will curtail widespread adoption of hybrids. Moves by the manufacturers to alter the image of hybrids from purely "green" technologies to the position of a performance option (performance without guilt) are, in our view, attempts to put forth a more favorable value proposition, focusing on the competitive core value of the Baby Boomer population.

Plug-in hybrids alter these rules somewhat, but are still duty-cycle sensitive. Those who drive out of range of the charge provided from the grid will experience a penalty associated with the added weight of the additional batteries needed to store the grid power. Those who drive on pure-electric power close to the point of recharge are also driving less efficiently than possible because they are carrying around the unused internal combustion engine and related systems during the battery-only portion of the duty cycle. Questions of residual value due to battery issues are apt to be at least as acute as with non-plug-in hybrids. While most consumers may actually drive in duty cycles within the range afforded by the plug-in hybrid, their mindset is that they need a vehicle with a full 300 mile range, and have no good reason to give up or exchange this expectation with something else.

There are some arguments that hybrids offer fuel savings on the highway due to their downsized engine, and that the extra power needed for acceleration can be obtained from the batteries. This is indeed the case. However, those who actually drive on the highways most of the time, or those who think they do and hence evaluate their car accordingly, can receive an equal or larger fuel economy boost at much lower initial cost with a downsized and turbocharged gasoline engine, which is also of significant benefit in the city.[3]

In sum, hybrids make the most sense in urban commercial applications where many miles are accumulated each year in stop and go traffic. The most attractive application are on heavy vehicles such as refuse trucks and urban buses where the financial savings due to a reduction in brake maintenance costs can help provide a payback to the hybrid.

Their exists a viable alternative to the hybrid technology that is far less sensitive to the way it is driven, and that has much less of a residual value risk, yet offers an equal if not greater fuel economy and performance benefit: the diesel engine. The diesel has been challenged to meet the emission regulations. However, technology is advancing and we believe that there exists a high probability that further reductions in emissions beyond the current Tier 2 standards are possible.

There remains a great deal of uncertainty over the future of emissions regulations beyond Tier 2. We believe that the vehicle manufacturers are reluctant to invest in manufacturing facilities for these engines based on a business case for the U.S. market due to this uncertainty. Policy-makers could move the situation forward by giving a clear signal to the automakers as to the level of post-Tier 2 emission standards. Technology developments and investments could then be made based on calculable risks rather than a very uncertain future governed by the unknown future of emissions regulation.

Recent market acceptance of diesel-powered cars and light trucks suggests that the historic U.S. market reluctance towards the diesel no longer exists. The remarkable acceptance of diesel technology in Europe, where the diesel market share exceeds 50 percent of the new car fleet, further supports this view.

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[2] Peter Valdes-Dapena, *Best cars with great gas mileage,* CNNMoney.com, May 8, 2006: "We've selected five—a luxury car, family sedan, sports car, crossover SUV and a subcompact—that are smart buys and easy on fuel. For each category, we've also mentioned two alternatives. None of the top cars are hybrids. That's because, with their added cost, hybrids aren't really a good value from a purely economic standpoint. But we've provided a hybrid choice in some categories for those who are willing to pay more to burn less fuel."

[3] Global Insight Inc. and TIAX LLC, *Future Powertrain Technologies, 2008 to 2020,* published 2001. Downsized and turbocharged gasoline engines yield about a 20 percent reduction in fuel consumption, or about the same benefit as a mild hybrid, when modeled over the FTP–75 test cycle.

Recent Market Acceptance of the Diesel
Exceeded the Expectations of Vehicle Manufacturers

Diesel Vehicle	Sales Expectations	Actual Sales	% Difference
Jeep Liberty	5,000	10,000+	100%+
Mercedes Benz E320	3,000	4,158	38%
VW US Diesel Sales (April 2006)	2,219	4,516	103%

Sources: Jeep: PR Newswire, 22 March 2005, E320: PR Newswire, 3 May 2005: VW: Green Car Congress, 8 May 2006

Question 2b:

How more or less likely is it that these radically new technologies—fuel cells, electric drive trains, or significant battery storage capabilities, for example—will be incorporated into cars rather than incremental innovations to internal combustion engines?

Historically, 'radical' technologies like these have not been incorporated in the vehicle fleet, primarily because they are not transparent to the consumer when assessed on the basis of one or more of the criteria of cost, utility and/or convenience. Incremental changes and innovations have been the experience—evolutionary rather than revolutionary

These and other advanced technologies offer further incremental improvements in fuel consumption. They will be adopted by the marketplace if and when they can meet the expectations of the core values of the consumers. Each of these, and indeed other innovations, are challenged to equal the current end expected evolution of the performance of the internal combustion engine. Concurrent achievement of competitive cost (initial and/or life cycle), range, refueling time, all-weather performance, well-to-wheels efficiency and greenhouse gas emissions etc. remain significant challenges.

The likelihood that these technologies can be incorporated into cars can be increased by also working through public education programs to influence the formation of core values of future generations, as discussed above. The best chance of this happening long-term is via Generation Z and their Gen X parents (who tend to have a more altruistic bent than other generations). By definition, it is impossible to change the core values of the current generations of consumers, but one can possibly modify consumer behavior by putting the benefits and shortcomings, if any, of these technologies into proper juxtaposition with current consumer core values, again through education. Incorporation of the technologies into cars will occur as both the technology and consumer perceptions evolve towards each other.

Regardless of how the end-result is achieved, we forecast that increases in efficiency of the vehicle through available or non-disruptive powertrain technologies will reach the point of diminishing returns once an improvement of approximately 30 percent has been achieved when compared to a baseline gasoline engine. To obtain improvements greater than this will require the use either alternative fuels or inherently more efficient lighter vehicles.

Summary:

What would be required to lead automakers to apply technology advancements to improving fuel economy?

The automotive industry will respond to increased demands for fuel economy from the consumer. Changes in consumer behavior that place a higher priority on fuel economy will result in the increased deployment of presently-available technologies such as hybrids, downsized and turbocharged gasoline engines, displacement on demand, etc.

A clear regulatory position on the future of emissions standards beyond Tier 2 will enable manufacturers to make an assessment of the likely future prospects for regulatory acceptance of the Diesel—the one technology that meets all current consumer expectations for performance while delivering a 20 to 30 percent improvement in fuel economy.

Changes in consumer behavior can be expected if and when the need for fuel consumption reduction resonates better with the core values of the consumer. The bulk of today's car buying public places high priority on the need for economic, physical and social survival. With current fuel prices and availability, fuel consumption has a lower priority than other vehicle attributes such as a high seating position (which increases aerodynamic drag), faster acceleration (that usually results in an engine that operates at off-peak efficiency most of the time) and high perceived levels of mobility and safety (that result in vehicles heavier than might normally be necessary).

Policies in the U.S. have lacked from the very beginning any component that attempts to change consumer behavior. Emphasis has been placed instead on maintaining mobility and lifestyle in a business-as-usual consumer environment.

What is needed is a series of coordinated efforts, all aimed at conservation. Programs that sponsor the development of high-risk technologies need to be continued simultaneously with public education programs that increase public awareness of the need to conserve, and to make it in their best interests to do so. It is likely that the high-risk technologies will have some limitations, or will change to some extent the normal expectations of today's vehicles with respect to range, refueling, convenience and performance. The core values of future consumer generations can be influenced by including in the education of current school-age children the need to conserve energy in all forms so that they embrace the new technologies and their differences from the vehicles of today.

Education programs need to be reinforced with fiscal programs that are in alignment with conservation goals. Programs that tax excessive consumption and reward conservation for new vehicles as well as those in-use will provide additional incentives to conserve.

What hurdles must hybrids, flex-fuel, and hydrogen-powered vehicles clear before the automobile industry, industry analysts, and the automotive press accept these technologies and consumers buy them?

Without a change in consumer values, transparency is the primary condition that must be met for the consumer to adopt a new technology in today's marketplace. Cost, reliability, durability, range, refuel time and convenience all need to be equal or better than the technology we seek to replace.

Hybrids suffer from higher costs, both initial and life cycle, as their fuel economy is generally insufficient to give a payback to the original purchaser during the first ownership period, and battery life issues cloud the resale value.

Hydrogen vehicles present a host of range, refueling and access challenges in addition to the technical issues and uncertainty of a net benefit when well-to-wheels issues are considered.

Of the three technologies mentioned, Flex-fuel vehicles offer the one technologically transparent solution, but only because the ethanol-containing fuel is not required. To make a difference in energy consumption, the six million FFVs on the road must have access to E85 at competitive costs. At the moment, there are less than 700 E85 stations nationwide, versus 175,000 refueling sites for conventional fuels.

How more or less likely is it that these radically new technologies—fuel cells, electric drive trains, or significant battery storage capabilities, for example—will be incorporated into cars rather than incremental innovations to internal combustion engines?

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They will be adopted by the marketplace if and when they can meet the expectations of the core values of the consumers. Concurrent achievement of competitive cost (initial and/or life cycle), range, refueling time, all-weather performance, well-to-wheels efficiency and greenhouse gas emissions, etc., remain significant challenges.

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Regardless of how the end-result is achieved, we forecast that increases in efficiency of the vehicle through available, non-disruptive powertrain technologies will reach the point of diminishing returns once an improvement of approximately 30 percent has been achieved when compared to a baseline gasoline engine. To obtain improvements greater than this will require the use either alternative fuels or inherently more efficient lighter vehicles.

BIOGRAPHY FOR PHILIP G. GOTT

Phil Gott is a Director for Automotive Consulting within the Automotive Group of Global Insight, Inc. He specializes in identifying technical/competitive advantages, and creating and implementing technical, business and/or market entry strategies to exploit them and achieve targeted business results. He has served the automotive industry since 1975 and has conducted a number of technology and market assessments or developed market entry strategies for many light vehicle technologies, including powertrain, electronic and mechanical systems as well as advanced materials.

Phil has primarily helped automotive vehicle manufacturers and component suppliers deal with the continuing changes in the automotive industry, whether the changes have been driven by regulatory, competitive or market forces. He both manages and participates in market research projects in which he has identified new product and market opportunities for component suppliers in the powertrain, driveline, chassis and suspension areas. He has managed major programs for vehicle manufacturers, providing the foundation for their long-term powertrain strategy. His work has also provided input to EPA, DOT and NASA on programs that support the development of regulatory standards, or assessing their impact. He has identified the need for, and led major multi-client studies assessing the likely changes in vehicle powertrain and electrical systems. To accomplish these, Phil draws upon his quarter century of industry experience, his mechanical engineering training (BS from Lafayette College) and his hands-on experience which includes building and testing experimental vehicles; designing, managing the construction and operation of one of North America's most advanced engine development laboratories; and preparing and developing five race cars, four of which are national or regional champions. He is a member of the Society of Automotive Engineers and the honorary engineering fraternity, Pi Tau Sigma. He also holds an SCCA National Competition license, campaigning an Acura Integra in the Northeastern U.S.

Phil has authored a number of industry publications including the award winning *Changing Gears,* a 400+ page history of the automotive transmission and how the industry responded to different market, societal and business forces to develop new transmission technologies. This hardbound book was published by the Society of Automotive Engineers in 1991.

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May 30, 2006

Chairman Judy Biggert
Energy Subcommittee
Committee on Science
US House of Representatives
390 Ford House Office Building
Washington, DC 20515

Re: RULES GOVERNING TESTIMONY - Letter of Financial Disclosure

Chairman Judy Biggert:

It is understood that the Committee on Science of the U.S. House of Representatives will hold a hearing on Assessing Progress in Advanced Technologies for Vehicles and Fuels on June 5, 2006.

The purpose of this communication is to provide written confirmation that Global Insight, Inc. has no sources to report nor has it received any amounts of federal funding which directly support the subject matter on which witness Philip G. Gott, Director of Automotive Custom Solutions within the Global Automotive Services Group of Global Insight, Inc., is testifying before the Committee. Furthermore, no funds have been received during the current fiscal year or either of the two preceding fiscal years by Mr. Gott or by Global Insight, Inc.

Sincerely,

Jamie J. Niedbalski

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DISCUSSION

Chairwoman BIGGERT. Thank you very much.

Now it's our turn, so each Member will have five minutes for questions. So the Chair recognizes herself for five minutes.

And this question, really, is for all of you and brief answers, please, so we can get through this. But which comes first, advanced fuels or advanced vehicles? It's the classic chicken or the egg question, I think.

How do we ensure that development and deployment of vehicles and fuels proceed in a coordinated fashion?

We'll start with you, Dr. Miller.

Mr. MILLER. In my view I think you're going to see advanced fuels before you see many of the long-term advanced technologies such as fuel cells or electric vehicles or even plug-in hybrid vehicles.

Clearly we have to have a national strategy and a national plan to do this coordination. But I think that has been put forth in the President's Advance Energy Initiative how we would do that. So I think there is a plan for doing so.

Chairwoman BIGGERT. Thank you.

Mr. Weverstad.

Mr. WEVERSTAD. I believe that it depends upon the advanced technology what comes first the fuel or the vehicle.

Clearly E85, an alternative fuel, we've got an industry nearly six millions chickens on the road, we're just looking for some eggs. So that one we've got.

When it comes to hydrogen we'll probably have to work at centrally fueled locations first and then develop the infrastructure.

Chairwoman BIGGERT. Thank you.

Mr. Hinkle.

Mr. HINKLE. I think that the cooperation—this is an area, particularly with hydrogen, where the cooperation between government and industry is really critical. And I think that the—what the Department of Energy is learning with their learning demonstration, their fleet validation programs that hooks—that hooks fuel companies to auto companies and develops not only a consciousness but the technologies that will enable these things to happen. And that's a fundamental change, I believe.

Chairwoman BIGGERT. Thank you.

Dr. Gibbs.

Dr. GIBBS. My view is that we simply need to make more of the fuels that we already know how to make. We need to make 50 billion gallons of ethanol and to make that a national priority, as I've indicated in my testimony. That does not exclude, of course, developing all these other technologies. But the demand certainly the beginnings of the infrastructure is already there for ethanol. We simply need to make more of it.

Chairwoman BIGGERT. Thank you.

Mr. Lovaas.

Mr. LOVAAS. Well, the first step that we can take actually before looking at the two fuels that we think offer a lot of promise, biofuels and electricity, is to improve the efficiency of conventional vehicles. So there's plenty of technology that can come right off the shelf and become a standard part of cars and trucks. And it will drive up efficiency. And then with biofuels you're probably going to have, since there are already substantial number of them out on the road, production of vehicles ramp up further before you have a ramping of the fuel. Because it's going to take a while for the ethanol industry to even make a dent in our transportation sector, which is 97 percent dependent on oil.

We all hear about ethanol and the substantial growth in ethanol in recent years. And it is impressive in percentage terms. In absolute terms it is a minuscule fraction of overall transportation fuel demand.

So on electricity, I'm not sure which is going to come first. I mean, we already have the grid in place if you're talking plug-ins, and we need to drive down the costs and drive up the range of batteries for plug-ins.

Chairwoman BIGGERT. Thank you.

Mr. Gott.

Mr. GOTT. Thank you.

For most technologies I would think the fuel has to be in place to give the public the confidence that it—that it exists that the vehicles that they might be in the future or consider buying can be driven and conveniently refueled. The diesel is a good case in point.

With a growing diesel fuel refueling network, Jeep expected to sell 5,000 diesel Liberties in the first year. They actually sold 10,000. Mercedes-Benz expected 3,000 E320s to be sold in diesel, 4,100 were sold. Volkswagen expected in—to sell about 2,200 diesel vehicles and 4,500 had been sold.

So clearly if you have a fueling infrastructure in place, you can certainly give the public the confidence needed to go ahead and buy the vehicles.

Chairwoman BIGGERT. Thank you.

Then, Dr. Gibbs and Mr. Weverstad, talking about there's about six million E85 fuel—flex-fuel vehicles on the road now and yet there's very few fueling stations for them. Why—why would the oil companies want to install facilities to encourage their customers to shift away from a product in which they have huge investments? And at one point I've heard that there's actually a contract with the distribution centers that prohibits some of them from putting in these stations. But why when they have these huge investment from the reserves in the ground all over the world to the refining and shipping capacity and even the standard gasoline pumps in the stations, why would they encourage that shift?

Dr. GIBBS. I can't speak to the oil company's motivation. I can only tell you that it costs about $30,000 to $50,000 to put a new ethanol pump. So it's not expensive. I think there might even be a subsidy in the Energy Bill.

Right now we have a temporary situation where there's a shortage of ethanol because of the switch to MTBE. The spot price of ethanol today is $3.50 a gallon. A year ago it was $1.30 a gallon. So we have enormous volatility in that market because of basically the lack of ethanol production capability. And I'm not defending the oil companies here. I'm just trying to describe the market.

Virtually all of the 90 some ethanol plants are concentrated here in the midwest. There are virtually none in California, none in central and east coast. That's the importance of cellulosic ethanol because we could begin to make it in other places.

But the answer is it's not that hard or expensive to put in an ethanol infrastructure. And there's an intermediate level of blenders, some of whom belong to the oil companies and some of whom are independent.

Chairwoman BIGGERT. Mr. Weverstad.

Mr. WEVERSTAD. I think that, you know, the oil companies would have to answer clearly for themselves. But from our perspective we are—we understand a company wouldn't want to make a large investment in an alternative fuel. They did it with methanol and it didn't work out well for them. So we were trying to create some customer pull. That's what our Live Green Go Yellow campaign was about.

We've actually worked with Shell and Chevron here in Illinois and in California. And a remarkable number of independents like Kroger and Meijer and many others to do demonstration projects to show them there really is a market for their fuels. We've had great results in the Chicago area at the—at the Shell stations and the Gas City stations actually selling more than they had anticipated.

It isn't while $30,000 may be higher than converting a pump, if they have to dig a new hole to put a new pump in, it can be quite expensive. So I think what—what the Congress can do to help them is to help provide some tax incentives for them to, indeed——

Chairwoman BIGGERT. I believe that there was one for the installation.

Mr. WEVERSTAD. Yes.

Chairwoman BIGGERT. It was in the Energy Bill to pass it on.

Mr. WEVERSTAD. And we need to continue that. That's—that's really what we need. We will try to create some customer pull. And if they can get some incentives, I think we can make it happen.

Chairwoman BIGGERT. Okay.

Then just a follow-up to Mr. Hinkle, the refueling infrastructure problem is even greater for hydrogen. What lessons from ethanol from E85 can we apply to the potential shift to hydrogen?

Mr. HINKLE. Well, you want to make sure you've got the molecules. That's—that's essential. But you need—you need a great deal of cooperation in advance, and that's—that's what I mentioned earlier. There's—the way that these things are—are rolled out is extremely important so that you don't build—so you don't build over capacity and don't build in prices with low demand over a long period of time.

So—and—and part of the earlier question that oil companies, certainly the oil companies that we work with most closely, I mean there's a simple and complex survival aspect of this. What business do you want to be in in 15 or 20 years? And so the—and you don't have to believe in peak oil to see that the constant development of new products is really important. So I think that cooperation with—with the needs of the—of the using device with—with a vehicle and the cooperation between the—the producer of the fuel is exceedingly important.

Chairwoman BIGGERT. Thank you.

And I have exceeded my time. So I will apologize and now yield to Mr. Honda.

Mr. HONDA. You're the Chair, Madam, and you don't have to apologize to anybody, especially in your home. And thank you very much for this opportunity.

Let me just make a real quick reaction or statement from what I heard this morning.

I heard that folks need to hear, the consumers need to have been challenged in terms of their core values. I think that's already been done at $3 plus per gallon.

The comment about having to exceed 30 percent efficiency in future cars in order for the consumers to consider alternative vehicles, that's been reached. My hybrid went from what I had in the car before is 20 miles to the gallon, which is a foreign car, to a hybrid, it went up to 42 miles on the highway and 50 in the city. So we've exceeded that.

The size of the vehicle was described to mean high seated and all the other stuff, which is nice. I had that in my van. But the hybrid technology has the ability to couple gasoline engines and hybrid engines together to be—to be put on a larger platform of a car. That is—that can be accomplished. So I think that what the consumer is looking at is when you all going to get started on this and what are we going to be doing in terms of providing that leadership in forcing—or having not the automobile industry to move forward, which is usually driven by consumers as we saw back in the '70s, but also I believe that the oil companies need to be put to task in terms of them providing the infrastructure. They have done that in the past and they can do it in the future because the amount of money they've earned over these past couple of years with the increase in gas is phenomenal. I think they can reinvest that money back into infrastructure that will provide the kind of services that consumers want.

Having said all of that, I believe we're on the right track and I think that a hearing like this is good because the community needs to hear what it is that we're talking about and what the experts are saying, and what's really available. The automobiles already available you say six million. That's six million here against over 220 plus million available vehicles in this country. What people don't know is the conversion kits cost between $200 to $500. I'd be willing to spend that because I spent that much in two months with the increase in gas.

Brazil has almost their entire fleet of cars out there are on flexibility fuel, E85. Most of those cars come from this country. And so the technology and the ability to do all that is ready. So the question really is what's our obstacle. And I ask the question that there are technological—there are barriers of economics and the barriers of political barriers.

And so my question back to you is I would like a candid response in terms of the barriers that you do see. And coupled with that question let me ask the other question: With hybrid plug-ins, I think it's great everybody's going to be able to do that if you have a garage. You have a lot of urban dwellers who park in the streets. How do you—how do you perceive how we deal with and provide that kind of service using plug-ins for those who are city dwellers who have to park their cars out in the streets?

I would appreciate a quick answer. It was a long question. Mr. Gott and Mr. Lovaas?

Mr. GOTT. In all due respect, Mr. Honda, while the numbers you quote are—are accurate for particular vehicles, the vast majority of the public isn't as forward thinking as you are. The most recent report from the EPA on trends in light duty motor technology suggests that the minimum weight of vehicles was around 1982. It's been getting heavier ever since. We show no—this is a sales weighted average. We show no change in that trend.

Acceleration time was minimal at about the same time, 1980. It's interesting we had minimum weight and minimum acceleration time or maximum acceleration time at the same point. It's gone from about 15 seconds down to 10 on a sales weighted average.

So the consumer hasn't gotten the message. And I don't think policy based on the assumption that the consumer has gotten the message is going to work. Yes, you can buy vehicles that are more efficient that have the advanced technologies. But the vast majority of the consumers are not yet buying them. And I think, you know, we need to address that issue.

Mr. LOVAAS. I would agree with my colleague if I hadn't read about the May sales figures for the automakers and seen just how much Toyota and Honda have jumped in terms of their market share, much to GM's mostly but also to Ford's costs. So I think consumers are getting it. Prices have not just spiked, but stayed high on a sustained basis. And EIA, even EIA which is very conservative in its Outlook traditionally, forecasts high prices as far as the eye can see. And I think consumers are realizing that.

Now in terms of what's needed, you have the price signals. But in terms of consumers being able to respond to those price signals, you have a lack of choices in terms of fuel and vehicles because our oil dependencies are hard wired into the county, so to speak. And we need to look back at two responses in the 1970s. You mentioned Brazil. There's another response in the 1970s that was successful. We adopted fuel economy standards here doubling the fuel economy of cars, driving down the oil intensity of the economy by about a third, which is part of the reason it's so resilient and in spite of the pain at the pump the consumers are feeling, the economy has not slipped into recession partly because oil intensity has dropped. And if we hadn't adopted those fuel economy standards, gasoline consumption—this is according to the National Academy of Sciences in a 2002 report, would be about 40 percent higher. And we would be all the more dependent on foreign sources of oil.

So we did—we did something then and we can do something similar now.

We can also look at Brazil. Right now, as you referred to, 70 percent of the vehicles sold in Brazil are flex-fuel vehicles. There's a mandate that ethanol be blended with gasoline at 20 to 25 percent. So that's about a quarter of the transportation demand fueled by ethanol derived from sugar cane in Brazil's specific case. Here it's just under three percent. Brazil prodded things along with policy in the 1970s in reaction to the last turmoil we faced in the marketplace because of oil embargoes and we adopted higher fuel economy standards in response to the same thing.

Both approaches have been pretty successful. And legislation that we consider to address this problem, policy responses that we consider should learn from those lessons.

Mr. HONDA. Thank you.

Dr. GIBBS. Did I hear in there that you'd like to hear about the hurdles to things like—let me just go over that from the testimony.

If you think about something like oil or gasoline, what you have is a liquid that has a very high energy density. So if there's an accident or something, if you see an oil fire or a gas fire you see a lot of energy being released. In contrast, biomass is very low density matter. So think big diesel trucks full of hay or corn stalks.

And the challenges in turning that material into a higher density fuel like ethanol involve solving this density problem.

For example, in building ethanol plants we would like to build them as large as possible to achieve economies of scale, but that would mean hauling all this low density biomass a large distance with diesel trucks and having the trucks come back empty. So we need new technology to resolve that conflict, that inherent conflict between the need to build larger plants and the need to deal with low density biomass.

The low density problem is a good thing in the sense that it creates lots of local jobs because you essentially have to build your plant wherever the biomass is.

We need critical components for converting that biomass. One of those is cellulase, the enzymes. Just one billion gallons of cellulosic ethanol would require an amount of enzyme that is about twice the annual production for all industrial enzymes in 1994. And that's just one billion gallons. And I am advocating that we produce 50 billion or more.

So we need to find ways to solve those problems.

There's another problem known as pretreatment. Essentially we've got to—to process very large amounts of low density material into the higher density fuel. And that's the hurdle and the expense.

Mr. HONDA. Thank you.

Mr. MILLER. I'd like to address the issue raised about plug-in hybrids and what do people who do not have a garage and must park their car on the street do for recharging those plug-in batteries.

I think there's a perception out there that plug-in hybrid batteries would require overnight charging, a period of six to eight hours. That simply is not the case. Hybrid batteries are much different than the old electric vehicle batteries in a sense that they can be charged much, much quickly, as little as one hour. So I think the solution to the problem that you raised is to install, for example, public charging stations at places where you may, for example, go to a restaurant and be there for an hour, you could plug in or charge. Or in parking lots, that would be another example. Presumably it would be much lower in cost to install an electric charging station than it would a fuel gas refueling station for alcohol or hydrogen, whatever. So I think that's one potential solution.

Mr. HONDA. If you have a suburban model in terms of how we think about recharging these kinds of cars?

Mr. HINKLE. I think there's many—many approaches to this.

Mr. HONDA. Okay.

Mr. HINKLE. And we realize that the decisional calculus of the consumer is not like that of fleet operators. And, after all, we're sort of a bunch of noble savages with regard to this. So who knows what—how much gasoline—how much the gasoline prices have to rise. And that's why fleets are so important, not only with respect to demonstrating the viability of these things, and this is true for any fuel not just—not just hydrogen.

Another thing with hydrogen, and it's also true with some of the biofuels, not so much with alcohols, but if you—if you don't have—and hydrogen is one of these things that's going to have even isolated national markets and regional markets for these things where the pricing is going to be a function of—it's going to be cost based and it's going to be a function of transparent market fundamentals. So the likelihood that government incentives, the tools that government has to deal with both the demand and supply side could actually—you could actually experiment with them and see—see how they work. Because hydrogen is not going to fungible worldwide, but it might be from region to region. It's like the electricity grid. I mean there—actually there is not one grid, as we know. There are several of them. So electricity prices vary considerably. And I would expect for a while hydrogen would do that, but it gives you the opportunity in combination, say, with things like with individual states and regions with a renewable portfolio standard, you would see some interesting phenomena there. So that's a speculation about what the markets might do.

Mr. WEVERSTAD. I'd like to answer many of the questions that I heard there. And if I've missed something, poke me and I'll try to come up with something.

But I'd like to start out by letting you know that actually GM has the most models of vehicles that get over 30 miles per gallon. And we lead in most of the categories in which we compete. Unfortunately, the world doesn't necessarily know that and that's a shame on us. We need to do a better job of explaining that.

I would also point out that the Toyota Prius that you speak of is a wonderfully engineered vehicle. But if you wanted to save gallons of gasoline, you could drive a new Chevrolet Impala with E85 and you'd actually save nearly 200 gallons more gasoline gallons in a year of operation. And you could drive a four-wheel drive Yukon and compare that to your Prius, you'd save 133 gallons of gasoline.

Mr. HONDA. I'd agree with you, except that the infrastructure is not there yet.

Mr. WEVERSTAD. That's—yes. That's our challenge and we need——

Mr. HONDA. Well, that's the point of my comment

Mr. WEVERSTAD. Right. We need—we need—we need to develop that and we—and we're doing what we can to make that happen.

As far as plug-in hybrids go, we don't want to throw away any technology. We need to look at all of them. But I will tell you as an engineer simple is better. Plug-in hybrids are the most complex. It has a complete electric system plus a complete gasoline system which makes it more complex and more difficult to engineer.

I would also point out that the lithium-ion batteries that we talk about today as the most promising, if you had a volume of the same size as a 20 gallon fuel tank, which is what most of our vehicles are, that would be equivalent to one quart of gasoline.

So there are some challenges and we're working on them.

Our problem with E85 is clearly engineers to calibrate and validate in more models; that's what's happened in Brazil. They don't have nearly as stringent emission standards or onboard diagnostic requirements. We don't want to give that up. E85 is cleaner and we want to keep—we want to keep that. And we need to develop the infrastructure.

Mr. HONDA. Could I just ask a real question that somebody in my District asked me, I didn't know my answer. Butanol versus ethanol, what's the distinction? Is there an advantage? Is that more dense or what?

Dr. GIBBS. Butanol is a four carbon alcohol and it is denser. It smells pretty awful. You can make it from biomass, but ethanol is a commodity today. We have futures being traded here in the Chicago Commodity Exchange. And I think that although Butanol could be an additive, ethanol really is going to be the central fuel in the infrastructure.

Mr. HONDA. Thank you, Madam Chair.

Chairwoman BIGGERT. Mr. Lipinski, the gentleman from Illinois is recognized.

Mr. LIPINSKI. Thank you, Madam Chairman. I'd again like to thank you for putting this hearing together. One of the most interesting hearings I've actually been to, not just because of the topic but also because of the quality of the witnesses. So I appreciate all the wisdom that you've shared with us today.

There's a couple of things. Well, one problem I was going to say, is I could go on forever, which none of us want to do here. Can go on forever with questions tapping into your knowledge here. But let me start here and let the Chair stop me when—when she's tired of hearing me. Hopefully, not right now.

Dr. Gibbs, I'm—I've been a big supporter of ethanol. And I think the Chairwoman has also been a big supporter of ethanol. The critics and I personally have come under attack, I think the Chairwoman has also, for supporting ethanol. The critics are—say that well it is really useless because you use more—you consume more energy the more fossil fuels, usually, in creating ethanol than you would if you were just using the oil to run the cars. So ethanol is really worthless. I want to put that to you and explain to me why ethanol is worthwhile.

Dr. GIBBS. That argument has been refuted. I'm blanking on the name of the professor who put that forward. Professor Pimentel's.

There are probably three different recent studies which are compendiums or studies combining, let's say, six or eight other studies to examine them on an equal bases, the most recent of which Professor Kammen from Berkeley. And what they've done is to simply plot the results from all these different studies. Pimental's which was negative, and all the others which were positive for ethanol. And show that in fact that is basically sort of an urban myth. Those early studies did not account for all the energy value that you get from ethanol and then made assumptions like we have to include the value of the lunch that the farmer eats, and things like this.

At any rate, and I could provide to the Committee if you'd like, the papers of Professor Kammen. On our website there's a link to Michael Wang, Dr. Wang at Argonne which essentially makes the case that there is a positive value.

Let me just very quickly——

Mr. LIPINSKI. How much of an increase?

Dr. GIBBS. You get about—about 25 percent more with—energy with corn. With cellulosic ethanol you get absolutely the best performance. And the reason for that is that you're able to use the other parts of the wood. The brown here and the brown in the wood is something called lignin. And so when you separate that out you can burn that. You get an additional process of energy instead of burning coal or natural gas. And then use the sugar to make ethanol. And the grams of CO_2 per mile and the energy balance are excellent for cellulosic ethanol.

Mr. LIPINSKI. Okay. It would be very good for you to provide us with that. Because, as I said, there's been—there's one particular media outlet who has an editorial saying that we were wrong because ethanol just is worthless. So it's important to have good information when making any of these public policy arguments.

I want to move on to Mr. Hinkle. I'm—certainly as I've—as I've talked about I was one of the individuals who introduced the H–Prize Act. I'm a big supporter of hydrogen.

The first question I have is our hydrogen internal combustion engines, has basic—have they been put aside? I've actually heard BMW, I believe, has a car coming out that is supposed to be hydrogen internal combustion engine. I'm not sure that's true. But from most of what I hear that technology has been abandoned. Has it?

Mr. HINKLE. Well it's been abandoned by the Department of Energy, which is different than being abandoned by industry.

BMW certainly is ready. They've made—they've had some announcements here recently that they may have a seven series V12 that's a biofueled vehicle that will—that will be able to use hydrogen and some others. And the emissions are remarkable and there's no loss in performance. I mean, it's the control system.

I mean, you can make these. You could—with hydrogen because of the enormous range of—of mixtures with air that it will tolerate, you could tune with the proper control system. You could tune one of these engines to do almost anything you wanted. It gives you—there's no other fuel that—that gives you that possibility. And, of course, you still have to have the supply. But BMW has done some pretty remarkable technical things, and they've also perfected a high pressure direct injection in the combustion chamber, which is a bit of a trick here. And people worked on that—they worked on that with the Formula 1 engines. Cosworth worked on that 30 years ago for Formula 1 cars and it wouldn't have fit into the rules. But they got some pretty dramatic horsepower increases. So—and Ford has done some—some good work on this.

So it's—you know, for the Department of Energy it's a resource constraint. You know, you got to work on the things that have the highest strategic value and you—without large amounts of money. And—and—but BMW, there's some—there's some smart people that have not abandoned this.

Mr. LIPINSKI. Do you think it's a mistake that DOE has abandoned it?

Mr. HINKLE. Well, given the resource limitations and—and their—their devotion to the—to the President's Initiative rather than what the expansive authorities allow in the—in the Energy Policy Act, there's a transition here. Perhaps there will be some—some thoughts about that. I don't know how much of a strategic mistake that is, but certainly the—a hydrogen fuel combustion—you know direct burn car offers a bunch of bridge opportunities just like hybrids do because of the drive system.

Mr. WEVERSTAD. Could I offer one of the reasons that we at GM have reduced our effort in internal combustion hydrogen engines is primarily due to the lack of energy density in hydrogen and the—the—you have all of the infrastructure problems that you needed with a fuel cell vehicle. And a fuel cell is twice as efficient to start with. So we wanted to take advantage of that efficiency. In order to get a—the BMW to operate like a regular car, they put a much larger engine and super charge it, which adds to the cost considerably. So we went for simple is better, and the fuel cell itself, the efficiency improvements help.

Mr. LIPINSKI. Okay.

Dr. Miller.

Mr. MILLER. Let me—let me clarify the record here. DOE has not abandoned hydrogen and internal combustion engines. And in fact, we are currently today doing research in our labs with hydrogen and internal combustion engines that is sponsored by the Department of Energy.

Mr. Hinkle is correct that it is a much smaller program than that for the fuel cell program. But as he correctly pointed out the Department does view hydrogen and internal combustion engines a transition technology, one that will allow us to get experience with hydrogen refueling stations, hydrogen in the marketplace and eventually be ready when the time that fuel cell vehicles are ready.

Mr. LIPINSKI. Thank you.

And one more question, the big question for Mr. Hinkle. I mean there are—in the H–Prize Act we give a prize for advances made in the production, distribution and storage and utilization of hydrogen. That's because there are major hurdles in all four of those areas.

Why do you believe that hydrogen has the potential—has such a great potential to be the fuel for—for vehicles in the future?

Mr. HINKLE. Well, the combination of strategic values at a 30,000 foot level are very important. The carbon aspects, the—the import, the wealth transfers from the imported oil bill. And then—and the efficiency gains. And so—and is it worth the complexity to—to evolve in this—in this fashion. It's an end point that combines, that essentially attempts to achieve the optimization of all those kind of features. And we're going to—as prices rise with gasoline and we're looking for alternatives and we—and—and the market mix evolves, we're going to have to from a policy standpoint make a lot of compromises with regard to how valuable is energy security? How valuable is a low carbon footprint and how valuable is—is high efficiency in—in achieving those things?

The H–Prize is—is—had a remarkable vote and just the—the political aspects of that are pretty—are pretty amazing. We'll see what it does in the Senate. And we were—we participated quite a bit with Representative Inglis's staff on—on inputs to that. It's a good bill. It's got some—and we're helping out Senator Dorgan and Senator Graham with that in the Senate.

But as—as the—and sorry, as the guys assured you in your hearing on this, it's not about the technology, it's about the human drama associated with this. And it lifts the—it tends to—these contests tend to lift the—the picture and the view and—and the—and the spirit of these—of these—of the technology and bring it into the—into focus for a lot of people who would otherwise not—not understand what this is.

Hydrogen is a very complex business, and it's—but it can't afford to be a geek's paradise. It's—it's got to be—it's got to get—it's got to be practical.

Mr. LIPINSKI. Well, since we're at the high note right there, I think I'll—I'll give my time.

Chairwoman BIGGERT. Thank you, Mr. Lipinski.

I wanted to—since this is a field hearing, I wanted to divert a little bit from what we normally do in the hearing. I would like to know, since we have all these people out in this audience, how many of you have hybrid cars raise your hands. High. Okay. How many of you would like to have a hybrid car? Ah. Okay. How many of you have the FlexFuel car? And there's some here. Great. And how many of you would like to have a hybrid plug-in when they become available? Okay. And how many would like to have a hydrogen car, which we have driven? Great.

Well, I think we have a great audience here and it's probably why you're here because you really believe in—in what we're trying to do here, and that is to, you know, cut down on the use of fossil fuels and really find alternatives.

I just wanted to say a couple of things. First of all, I don't know if you can answer, but I've talked to a lot of people that say they want a hybrid and they go to the car dealers and they're not available. There's a long waiting list, it's a lot more expensive than a regular car even though there's a tax credit. And you must know that there is a tax credit now. Some of you bought your hybrids probably before—before the last Energy Bill, but there is a tax incentive for you to buy a hybrid car. And then—but still it's more expensive.

And—and I also had received something from—from a member, I think a member of the audience that—that says that they noticed that the price for E85 at a local retail gas station fluctuates in direct proportion with the price of gasoline. It says if gasolines increases 20 cents, then E85 increases 20 cents. And he's saying that it should—the only commonality between these two products is 15 percent gasoline, which then should represent only a three percent increase for the 20-cent example.

So this is the cost of—and right now has been talked about, we only have—or we're really using mostly ethanol and the price seems to have gone up when suddenly ethanol has been very popular for use in ethanol—or the price of corn, I should say. The bushel of corn has gone up so much.

So why, if you can give me an answer, why the price of ethanol goes in direct proportion to the gasoline? I would like to hear that.

And also do you know, and particularly Dr. Gibbs and maybe Mr. Weverstad, with the cars—one other thing about the car, too, I'd like you to come back to is you talk about you have 14 models that all feature good gas mileage. But are these cars—you know, we—we in the United States have a love affair with the SUV. And I think what has happened is cars—manufacturers have tried to take that into account in making cars that have low—lower gas mileage and are hybrids. And that's a good thing. But are the models of your car the kind that, you know, the car that has all the bells and whistles on it and has as well as the good gas mileage? So if we want to start with maybe Dr. Gibbs?

Dr. GIBBS. The price of ethanol is—should be tied to the price of gas and the current value normally would be that whatever the price of—of wholesale unleaded is plus the federal subsidy, which is about 51 cents. Right now that premium is running probably $1.50. As I mentioned, spot ethanol is $3.50, which is of course out of sight. A year ago it was a $1.30.

I think the answer is as we make more ethanol, the price will come down. But in the short-term ethanol is more expensive that gasoline on a—on an energy basis. And so the hope is as we make more and more of it. And right now we're in a crunch because the eastern states have had to drop MTBE. So they're actually probably taking ethanol out of our gas in the midwest and sending it to the east coast.

Chairwoman BIGGERT. So how soon do you think that that will happen? You talked about ethanol now is a product on the exchange, which I think is going to change the way that we think about ethanol.

Dr. GIBBS. Well, again, it's production capacity. I mean our total capacity is only about five billion gallons out of, you know, versus 140 billion gallons of gas. When we get up to tens of billions of gallons, and just as a benchmark if we were just to go to E10, that is forget E85 and just go to E10, we need 14 to 21 billion gallons of ethanol to do that. We cannot do that from corn.

Chairwoman BIGGERT. So it's back to the old supply and demand?

Dr. GIBBS. Right. So supply and demand. And I think that the cellulosic, the cheaper technology is hoped for, DOE has always projected it, but it's always five years away. So we have to get there.

Chairwoman BIGGERT. Thank you.

Mr. LOVAAS. Well, one of the more interesting components or experimental provisions, shall we say, of H.R. 4409, the *Fuel Choices for American Security Act,* is removing the tariff on imported ethanol. We do not apply a tariff to oil imports and yet we——

Chairwoman BIGGERT. That's Dr.—or Representative Kingston's Bill?

Mr. LOVAAS. Kingston's Bill, exactly. So—and this would—if this were enacted, it would provide an immediate spike in supply and help to remedy the fact that, you know, you do have this price problem, that is it's a product of economics, supply versus demands. So——

Chairwoman BIGGERT. Even those in Illinois where the corn producer will have to look at that bill.

Mr. Weverstad.

Mr. WEVERSTAD. To answer your question on our over 30 mile per gallon vehicles, they're not just small stripped down vehicles. You can buy a full size Chevrolet Impala that gets over 30 miles a gallon on the highway. It's—and what we're maybe most proud of is our full size sports utilities that are brand new this year. The combined average 55 city/45 highway on that full sized sport utility vehicle now exceeds 20 miles a gallon, which is a first in the industry for a vehicle that size to give that much utility and that much—people need those vehicles if they pull trailers or there are plenty of uses for those vehicles and they need good fuel economy as well.

With regard to why the ethanol prices are—are—follow gasoline, I can't answer that. I don't—I don't know how they set prices on gasoline. I just know they seem awfully high.

Chairwoman BIGGERT. Thank you.

Mr. Honda.

Mr. HONDA. Thank you, Madam Chair.

I was just going to make another comment. If the—if the goal is to be more independent of fossil fuel, what we haven't talked about is the utilization of solar on individual homes where individual homes will have what we call smart meters or net metering where you can use the static position of homes all across this country. And it'll vary based upon our climate. But it seems to me that coupling another technology with the technologies we're talking about relative to vehicles should be something that we should be including in our conversation. And so I was wondering in terms of electricity and plug-ins and all that sort of stuff, I think we depend upon two percent of our electricity is from petroleum, eliminate that. And we're trying to move away from carbons, even though carbons are our good friend that come from water and air rather than from petroleum or from the ground, it makes good sense.

I was curious what other ideas you might have in conjunction with the mix and matching of our technologies? You may have to be brief because we only have a few minutes.

Mr. LOVAAS. Oh, we don't.

I'm—I'm not that much of an expert on electricity. But as you said, two percent of our electricity comes from oil. So whatever we do in this sector with solar renewables, such as wind, isn't going to have much of an impact on our oil dependence. But shifting to those technologies will help and it will also help to displace the use of coal which is, frankly, a concern of NRDCs if we do using electricity more and more as a fuel in transportation. Unless we use surplus capacity, which is possible because a lot of people are going to be fueling up at night at their homes using off peak surplus capacity, and we don't have to build new plants, you know, that's okay. But if we have to build new plants, if we're concerned about the environment and about climate, then we have to make sure that we're cleaning up the grid and shifting away from coal to renewables.

Chairwoman BIGGERT. The gentleman yields back.

Mr. Lipinski for a quick question.

Mr. LIPINSKI. Following up on that—on that use of renewables, I want to ask Mr. Hinkle about the use of renewables to produce hydrogen and how—how far you think that is a way to have maybe where you can produce hydrogen at your own home through a—maybe a solar? Because—I mean, this is something that's seen. There is a future of hydrogen, use solar energy at home, produce electricity with the solar, produce the hydrogen and how far away do you think something like that is?

Mr. HINKLE. Well, Honda of course makes—makes a device now, it's not based upon solar, but it's—and it's a—but it's a bite size piece, it's a home sized piece that generates hydrogen.

There needs to be just like on a very large scale with electrolyzers, there's a bunch of work still needs to be done on those even those there's been a commercial—a commercial technology for a long time. But the thing about hydrogen, it's scalable from very small to very large. And there still needs to be plenty of thinking and engineering and science that goes into that. But renewables, we did a lot of work when I worked for Senator Dorgan on wind on the wires in the Northern Great Plains. And wind on the wires for hydrogen could be very important, especially with the Western Area Power Administration, which is part of DOE. And that goes from the northern great plains into the great southwest and into California.

Hydrogen in those high growth urban areas from renewable sources is going to be important, but you've got to do a bunch of stuff with the grid, you've got to invent some different control mechanisms and management for those and you've got to build things and you've got to do some things with extra materials to increase the throughput, the power throughput in the corridors where siting is a problem.

So there's a big system problem associated with lots of renewables for hydrogen. But for solar, there's some interesting things and I hope California is able to—and Arizona are able to do things like that.

Mr. LIPINSKI. Thank you.

Chairwoman BIGGERT. Thank you very much.

Thank you all. We've great panel of witnesses today. Thank you for your expert testimony and I think that we've all learned a lot and appreciate you being here.

If there's no objection, the record will remain open for additional statements from the Members and answers to any follow up questions from the Committee. Without objection, so ordered.

With that, this hearing is now adjourned.

[Whereupon, at 12:02 p.m. the Subcommittee was adjourned.]

Appendix:

ADDITIONAL MATERIAL FOR THE RECORD

EDITORIAL

Chris Somerville is director of the Department of Plant Biology, Carnegie Institution, and a professor at Stanford University. His research concerns plant cell and molecular biology.

The Billion-Ton Biofuels Vision

IN 1895, SWEDISH CHEMIST SVANTE ARRHENIUS PRESENTED A PAPER TO THE STOCKHOLM Physical Society titled *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground*, in which he argued that the combustion of fossil fuel would lead to global warming. He was right, so we must deal with the consequences of global climate change and somehow meet our expanding energy needs while limiting greenhouse gas emissions. Earth receives approximately 4000 times more energy from the Sun each year than humans are projected to use in 2050. Some of that energy can be captured through a variety of "renewable" sources, but the only form of solar energy harvesting that can contribute substantially to transportation fuel needs at costs competitive with fossil fuel is that captured by photosynthesis and stored in biomass.

Brazil now obtains a quarter of its ground transportation fuel from ethanol produced by the fermentation of sugarcane sugar, and in the United States, approximately 90 corn grain-to-ethanol refineries produce about 4.5 billion gallons of ethanol annually. The U.S. Energy Policy Act of 2005 would increase that production to 7.5 billion gallons by 2012, but the United States currently uses about 140 billion gallons of ground transportation fuel per year. To replace 30% of that amount with ethanol of equivalent energy content, as proposed recently by the Secretary of Energy, will require about 60 billion gallons of ethanol. A recent analysis* concluded that the United States could produce about 1.3 billion dry tons of biomass each year in addition to present agricultural and forestry production. Because it is theoretically possible to obtain about 100 gallons of ethanol from a ton of cellulosic biomass (such as corn stover, the stalks remaining after corn has been harvested), the United States could sustainably produce about 130 billion gallons of fuel ethanol from biomass. In addition to a positive effect on the release of greenhouse gases, a biofuels program on this scale would have substantial economic and strategic advantages.

The creation of a new industry on that scale will require much basic and applied work on methods for converting plant lignocellulose to fuels, because several significant problems must be overcome to make the process ready for large-scale use. For example, cellulose is a recalcitrant substrate for bioconversion, and unacceptably large amounts of enzymes are required to produce sugar. Lignin occludes polysaccharides and inhibits enzymatic hydrolysis of these carbohydrates; energetically expensive and corrosive chemical pretreatments are required for its removal. The yeast currently used in large-scale ethanol production cannot efficiently ferment sugars other than glucose. And relatively low concentrations of ethanol kill microorganisms, requiring an expensive separation of the product from large volumes of yeast growth medium.

These and other technical issues associated with this emerging industry have potential solutions, and many incremental advances can be envisioned. However, substantial public and private investment will be needed to meet the nation's goals. For instance, competitive funding for basic research in plant biology by all federal agencies totals only about 1% of the National Institutes of Health's budget. Small wonder that we do not know basic things such as the composition of the enzyme complex that synthesizes cellulose. Hopefully, a new U.S. Department of Energy (DOE) report† that outlines the scientific issues will help set the direction for increased funding in this area.

A national biofuels strategy will ultimately depend on massive support for basic curiosity-driven research in many aspects of nonmedical microbiology, plant biology, and chemical engineering. A fivefold increase in federal support during the next decade could readily be justified by the projected economic gains from the accelerated development of a cellulosic biofuel industry. To ensure parallel progress on the many different components of a biofuels strategy, it may be necessary to create a mission-oriented project similar to the Manhattan Project. Indeed, several of the national laboratories that were founded during the Manhattan era also pioneered some aspects of biofuel technology and could be a powerful source of relevant scientific and engineering expertise.

– **Chris Somerville**

10.1126/science.1130034

*R. D. Perlack *et al.*, *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply* (DOE/GO-102005-2135, Oak Ridge National Laboratory, Oak Ridge, TN, 2005). †U.S. DOE, *Breaking the Biological Barriers to Cellulosic Ethanol: A Joint Research Agenda* (U.S. DOE Office of Science and Office of Energy Efficiency and Renewable Energy, 2006) (available at www.doegenomestolife.org/biofuels/).

broadly applicable opens a number of doors to better theoretical and practical understanding of group dynamics. From an evolutionary perspective, the costs and benefits of behavioral choices in groups change dramatically depending on how other group members respond, and they can be deciphered only through quantitative models of behavioral cause and effect. Furthermore, if the organizational transitions seen in locusts are as fundamental as the SPP model suggests, then their presence is not the result of selective fine tuning; for better or worse, these and perhaps other features may be evolutionarily unavoidable aspects of grouping. In applied terms, intelligent management of natural resources depends on understanding grouping transitions not only in desert locusts, where we may want to derail collective motion, but also in cases such as overexploited migratory fish stocks, where we need to avoid collapse of reproductive aggregations to prevent catastrophic population declines.

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10.1126/science.1127548

CHEMISTRY

Toward Efficient Hydrogen Production at Surfaces

Calculations are providing a molecular picture of hydrogen production on catalytic surfaces and within enzymes, knowledge that may guide the design of new, more efficient catalysts for the hydrogen economy.

Jens K. Norskov and Claus H. Christensen

Hydrogen is considered by many to be a promising energy currency, particularly for the transportation sector and for mobile devices (*1*). The combustion of hydrogen yields water as its only waste product, and hydrogen is a perfect fuel for fuel cells. In most hydrogen-producing technologies, a solid surface catalyzes the required chemical reactions. Higher efficiencies require the development of better catalysts. Recent studies have raised hopes that combined computational and experimental surface studies can aid the design of new catalysts.

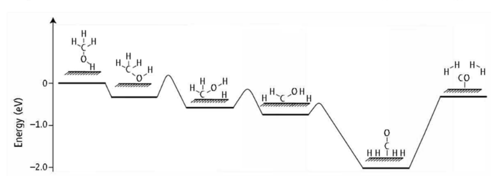
To realize a hydrogen-based fuel economy, hydrogen must be produced in an efficient and sustainable manner. Today, most hydrogen is produced from fossil resources by steam reforming, a process in which steam reacts with hydrocarbons in the presence of a metal-based catalyst. Sustainable alternatives include biological or catalytic degradation of biomass and electrochemical or photochemical splitting of water. But irrespective of how the hydrogen is produced, the process is endothermic and requires a considerable amount of energy input.

In most steam-reforming processes, this energy is provided as heat (*2*), whereas water splitting is usually performed electrochemically or photochemically (*3*). These processes require bonds to be broken and new bonds to be made, chemical transformations that are activated and typically catalyzed by solid surfaces. Today, the development and optimization of catalytic surfaces is usually based on an intuitive trial-and-error approach. Rational catalyst development strategies would be greatly facilitated by an improved molecular-level knowledge of how chemical reactions proceed on solid surfaces. Recently, new detailed insights have been provided by density functional theory calculations.

Industrial steam reforming of natural gas—that is, $CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$—is conducted with nickel catalysts at temperatures of ~800 °C and provides a convenient and cost-effective method for hydrogen production. Ideally, four hydrogen molecules are formed per methane molecule when the methane reacts with water. Today, compact hydrogen-production facilities with capacities of more than 250,000 m^3 H_2 per hour can be designed (*2*).

Steam reforming of renewable bioresources is also a viable route to large-scale hydrogen production. Glucose can be reformed in water at surprisingly mild conditions, producing more than six hydrogen molecules for each glucose molecule (*4*). Ethanol, available for example through fermentation of biomass, can also be steam-reformed in the presence of oxygen. The required heat is supplied directly by combusting some of the hydrogen produced; such an autothermal process yields five hydrogen molecules for each ethanol molecule (*5*).

The catalytic conversion of alkanes, alcohols, or carbohydrates with water into hydrogen and carbon dioxide are complex multistep chemical reactions. It is not possible to pinpoint a priori why one catalytic surface performs better than another. For even the simplest alcohol—methanol—the number of elementary reactions associated with its decomposition and the subsequent formation of molecular hydrogen is large (*6*). However, calculated potential-energy dia-



Understanding catalyst activity. This calculated potential-energy diagram (*6*) shows one way in which methanol decomposes into molecular H_2 and adsorbed CO over a platinum surface. Elucidating this and other competing pathways for decomposition may help to devise new catalysts.

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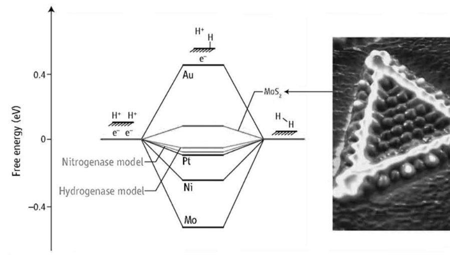

Aiming for a shallow well. This calculated free-energy diagram for electrochemical H_2 formation (*9*) shows that some metal surfaces bind hydrogen too strongly to make hydrogen evolution likely at room temperature, whereas others bind it too weakly to allow hydrogen adsorption at all. The aim is a shallow well that allows both adsorption and evolution. **(Inset)** Scanning tunneling microscopy image of MoS_2 nanoparticles (*12*), showing the edges where hydrogen can adsorb and H_2 evolve.

grams (see the first figure) can provide a direct identification of the highest activation barriers, providing information on which reaction intermediates need to be stabilized to improve the overall reaction rate. With this knowledge, one can attempt to modify the surface structure or composition in a search for more active catalysts.

There is also renewed interest in the interaction of water with surfaces and in the electrochemical splitting of water into molecular oxygen and hydrogen (*7*, *8*). For the hydrogen evolution reaction, $2(H^+ + e^-) \rightarrow H_2$, a molecular picture of hydrogen evolution has been proposed to explain why platinum is an outstanding catalyst for this reaction, whereas other metals close to platinum in the periodic table (such as nickel or gold) are not (*9*). Free-energy diagrams calculated with density functional theory show that hydrogen adsorption on platinum surfaces is associated with the smallest free-energy change (see the second figure) (*9*).

Similar calculations have modeled the interaction of atomic hydrogen with the catalytically active sites of two classes of enzymes—hydrogenases (*10*) and nitrogenases (*9*)—which catalyze hydrogen evolution. The results indicate that the enzymes have hydrogen adsorption properties very similar to those of platinum (see the second figure). The catalytic sites in these enzymes contain no noble metals but rather sulfur complexes of nickel, iron, and molybdenum. Nature seems to have found an inexpensive way of imitating platinum for this purpose.

These calculations open up the possibility of designing surfaces with nanometer-scale structure that share some of the enzyme properties. One promising material involves nanometer-scale MoS_2 particles (see the second figure, inset). This system yields reasonable hydrogen evolution rates (*9*), but is not as active as platinum. The biological examples indicate that there may be other metal sulfides that are better catalysts than MoS_2, but very little research has been done, either theoretically or experimentally, in this direction.

More efficient hydrogen production methods will require more efficient catalysts. The challenge is to find inexpensive, active, and stable nanostructured materials designed for optimal performance, be it in the production of hydrogen from bioresources or via electrochemical or photochemical routes. The emerging molecular-level picture of surface reactions may soon allow us to design such catalytic surfaces on the basis of insight (*11*).

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ATMOSPHERE

Aerosols, Clouds, and Climate

The chemical composition of aerosol particles is much less important than their size in determining their ability to nucleate clouds, a result that will clarify aerosol effects on climate.

Daniel Rosenfeld

The power of greenhouse gases to warm the planet may have been underestimated, because much of it has been masked by the cooling effects of aerosols from combustion and other pollution sources (*1*). Aerosols also reduce vital water resources in densely populated semi-arid regions by suppressing precipitation (*2*). Because pollution aerosols act as cloud condensation nuclei, clouds forming in a more polluted atmosphere contain a larger number of smaller drops that are slower to merge and fall as precipitation. As a result, the clouds are brighter, thicker, longer-lived, and more extensive, thus reflecting more sunlight back into space and partially mitigating global warming.

These aerosol effects are poorly quantified and represent the greatest uncertainty in our understanding of the climate system. The chemical composition of an aerosol particle is crucial to its ability to nucleate a new cloud droplet, yet measuring the chemical composition of aerosol populations on climatologically meaningful scales is very difficult. But on page 1375 of this issue, Dusek *et al.* (*3*) show that the size distribution of such aerosol populations—a property that is easier to measure than chemical composition—can explain most of the variability in their cloud drop nucleating activity. This result should make it easier to quantify the effects of aerosols on clouds and hence on climate.

The cloud drop nucleating activity of an aerosol particle is determined mainly by how many water-soluble molecules and ions it can release into a newly nucleated droplet. Chemistry determines the number of soluble molecules and ions per unit mass of aerosol. This number, multiplied by the mass of the particle, determines its cloud drop nucleating activity. This is how size

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A FURTHER ASSESSMENT OF THE EFFECTS OF VEHICLE WEIGHT AND SIZE PARAMETERS ON FATALITY RISK IN MODEL YEAR 1985-98 PASSENGER CARS AND 1985-97 LIGHT TRUCKS

Volume I: Executive Summary

DRI-TR-03-01

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EXECUTIVE SUMMARY

The effects of passenger car and light truck curb weight, wheelbase, and track reduction on crashworthiness-and-compatibility and crash avoidance have been assessed, in terms of the net change in the total number of US fatalities in six crash types representing the majority of fatal crashes. This analysis was based on 1995-99 calendar year accident data[1] from seven states[2] involving 1985-98 passenger cars and 1985-97 light trucks[3], using the methods described by Kahane in Ref 2 and suitably extended for the purpose of this analysis. These results:

- are in good agreement with the results previously reported in Ref 1, in which the overall effect of passenger vehicle weight reduction, *and implicit corresponding size reduction*[4], on US fatalities were estimated and found to be not statistically significant; and

- provide additional insight into the effects of passenger vehicle curb weight, wheelbase, and track reduction on crashworthiness, compatibility, and crash avoidance, in terms of the overall number of traffic fatalities, which have not been addressed by previous studies.

These results indicate that overall, curb weight reduction tends to decrease the overall number of fatalities, but typical corresponding reductions in wheelbase and track tend to increase fatalities by a nearly equal amount, and that the overall net change is not statistically significant at the 0.05

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[1]This was the most recent 5 year period for which US fatal (FARS) and state accident data were available during the time period for the data analysis reported in Ref 1 (June 2001-January 2002).
[2]Only those states with VIN prefix data were used in this analysis. The seven states were those for which suitable accident data were available as of January 2002.
[3]The range of vehicle model years was determined by the vehicle classification algorithms that were used. C. Kahane of NHTSA supplied these algorithms.
[4]The results reported in Ref 1 did not control for changes in vehicle size parameters. Therefore curb weight was effectively a surrogate for all vehicle size and weight parameters and the results in Ref 1 implicitly include effects due to changes in vehicle size.

level. For example, the estimated net change in fatalities that would have occurred in 1999 if there was a 100 lb passenger car and light truck weight reduction, *while keeping the vehicle wheelbase and track constant*, would have resulted in a net decrease of 799 ± 316 fatalities, out of the 37,633 US fatalities that occurred in 1999[5]. The estimated effect of a 100 lb weight reduction and corresponding reductions in wheelbase and track are summarized in Table 1. The ±2-sigma confidence bounds for these results correspond to a 95% confidence interval, provided the assumptions used in this analysis are valid.[6] Therefore, based on these results for 1985-98 model year passenger cars and 1985-97 model year light trucks in 1995-99 calendar year accidents in seven states, the number of traffic fatalities in the future could be reduced by decreasing the weight of the passenger vehicle fleet weight while maintaining the wheelbase and track constant.

[5] There were 41,611 US traffic fatalities in 1999 (Ref 4), including collisions involving three or more vehicles, two or more vehicles and pedestrians or bicyclists, and also collisions not involving passenger cars or light trucks (i.e., collisions involving motorcycles or larger trucks but not passenger cars or light trucks). The 37,633 fatalities analyzed herein were only those involving passenger cars or light trucks, or both, in one or two vehicle collisions. There were 6,881 fatalities involving both cars and light trucks, which are affected by both passenger car and light truck weight reduction, but which were counted only once in the total.

[6] Kahane suggested using a ±3-sigma confidence interval to interpret the aggregate regression results with exogenous control for driver factors because the exogenous coefficients could have introduced propagated sampling or nonsampling errors (Ref 2, pp 138-139). However, this situation does not apply to the results of this additional analysis.

Table 1. Estimated Effects of a 100 lb Vehicle Weight and Corresponding Wheelbase and Track Reduction on 1999 US Fatalities, Based on Data for 7 States

Vehicle Type	Fatalities in 1999 US Crashes[1]	Estimated Net Change in 1999 US Fatalities due to[2]							
		100 lb Curb Weight Reduction		Typical Corresp. Wheelbase Reduction[3]		Typical Corresp. Track Reduction[4]		Combined Weight and Size Reductions	
		Est.	(2σ)	Est.	(2σ)	Est.	(2σ)	Est.	(2σ)
Passenger Cars	25,335	**-580**	**(260)**	**368**	**(174)**	**191**	**(134)**	-21	(340)
Light Trucks	19,179	**-219**	**(179)**	**174**	**(81)**	**106**	**(104)**	61	(222)
Total	37,633	**-799**	**(316)**	**542**	**(192)**	**297**	**(170)**	40	(406)
$\pm$2 sigma confidence bounds		-1115 to -483		350 to 734		127 to 467		-366 to 446	

Sources and notes:

[1]IIHS, cited in Table 2-3 of Ref 3.

[2]Based on data for 7 States.

[3]"Typical" wheelbase reduction is 1.01 in for passenger cars and 1.21 in for light trucks.

[4]"Typical" track reduction is 0.34 in for passenger cars and 0.57 in for light trucks.

Bold numbers are statistically significant at the 0.05 level, i.e., the estimated value exceeds the $\pm$2 sigma confidence interval.

The estimated effects of a 100 lb weight reduction and corresponding reductions in wheelbase and track by crash type are also in good agreement with the results previously reported in Ref 1. The results in Ref 1 were based on linear regressions of aggregated fatality rate data for the entire US with exogenous control for driver factors. The results in Table 1 were based on logistic regressions of disaggregated data and linear regressions of aggregated data for seven states[7].

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[7] Kahane used three basic approaches to estimate the effects of weight-and-size on fatalities in Ref 2. The first approach involved using logistic regression of disaggregated data and linear regressions of aggregated data. The second approach involved using linear regressions

The results also indicate that reductions in vehicle weight, wheelbase, and/or track would significantly increase the numbers of fatalities due to crashworthiness-and-compatibility and/or crash avoidance in some types of crashes, and significantly decrease the numbers of fatalities in other types of crashes. The net effect of these opposing trends is they tend to cancel each other out. For example, a 100 lb reduction in passenger car weight would significantly reduce the numbers of fatalities due to crashworthiness-and-compatibility in crashes with other passenger cars, but typical corresponding reductions in wheelbase and track would significantly increase the number of fatalities in the same crashes. The combined effect of weight, wheelbase, and track reduction in the proportions indicated is not statistically significant.

Due to the methodology used (i.e., adapted from Ref 2), the statistical significance of a trend is independent of the magnitude of the weight and/or size reduction, provided the change is relatively small.[8] For example, the results in Table 1 indicate that a 100 lb passenger car curb weight reduction, controlling for wheelbase and track, would decrease the overall fatalities by 580 ± 260, which is statistically significant. Using the same methodology, a 10 lb weight reduction would result in a 58 ± 26 decrease in the number of fatalities, which is smaller but still statistically significant. Therefore, the trend that passenger car curb weight reduction decreases the overall number of fatalities is statistically significant. This and other statistically significant trends in the results for passenger cars and light trucks are summarized in Tables 2 and 3.

The sensitivity of the results to data used in the analysis was also assessed. This included the sensitivity to different samples of induced-

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of aggregated data. The third approach was similar to the second approach, but added exogenous control for driver factors based on results from the first approach. The main results in Refs 1 and 2 are based on this third approach. The results in this report are based on the first approach, suitably extended to estimate the separate effects of vehicle weight, wheelbase, and track on vehicle crashworthiness & compatibility and crash avoidance.

[8] This result is based on a linear assumption that should be reexamined for weight changes much larger than 100 lb.

exposure and non-fatal accident data; the exclusion of data from each of the seven states one at a time; and the exclusion of “sporty cars” or “sporty light trucks”. The results for passenger car wheelbase and track were sensitive to the exclusion of data for “sporty cars”. This sensitivity was attributed to possible model overparameterization due to less variation in car wheelbase and track, and fewer cases overall, in the data for just 4 door sedans and hatchbacks. The sensitivities of the results for the other tests were small relative to the 2-sigma confidence intervals and the results appear to be stable with regard to these various sensitivity tests.

Table 2. Summary of the Estimated Effects of Passenger Car Parameter Changes on Fatalities

Passenger Car Parameter Change	Estimated Net Change in 1999 US Fatalities[a]					
	Due to Crashworthiness and Compatibility (F/A)		Due to Crash Avoidance (A/VRY)		Combined (F/VRY)	
	Est.	(2σ)	Est.	(2σ)	Est.	(2σ)
100 lb Curb Weight Reduction	**-472**	**(259)**	-108	(156)	**-580**	**(260)**
1.01 in Wheelbase Reduction	**514**	**(172)**	**-147**	**(106)**	**368**	**(174)**
0.34 in Track Reduction	**165**	**(134)**	26	(81)	**191**	**(134)**
Sum of Combined Weight and Size Reductions	208	(339)	**-229**	**(205)**	-21	(340)

Notes:

[a]Based on 25,335 fatalities in 1999 US crashes involving passenger cars.

Bold numbers are statistically significant at the 0.05 level, i.e., the estimated value exceeds the ± 2 sigma confidence interval.

Table 3. Summary of the Estimated Effects of Light Truck Parameter Changes on Fatalities

Light Truck Parameter Change	Estimated Net Change in 1999 US Fatalities[a]					
	Due to Crashworthiness and Compatibility (F/A)		Due to Crash Avoidance (A/VRY)		Combined (F/VRY)	
	Est.	(2σ)	Est.	(2σ)	Est.	(2σ)
100 lb Curb Weight Reduction	-155	(179)	-65	(114)	**-219**	**(179)**
1.21 in Wheelbase Reduction	41	(81)	**133**	**(53)**	**174**	**(81)**
0.57 in Track Reduction	88	(103)	17	(67)	**106**	**(104)**
Sum of Combined Weight and Size Reductions	-25	(222)	86	(143)	61	(222)

Notes:

[a]Based on 19,179 fatalities in 1999 US crashes involving light trucks.

Bold numbers are statistically significant at the 0.05 level, i.e., the estimated value exceeds the ± 2 sigma confidence interval.

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January 2006

2006 KPMG Global Auto Executive Survey

In this year of record sales for some, record losses for others, and – not coincidentally – record sales incentives, the automotive executives KPMG International surveyed are increasingly mixed in their sense of a wide variety of issues. While there are a few constants, such as the belief that consumers want quality and safety, and some obvious changes – a big jump in the number of those who think hybrid sales will increase dramatically – executives are often sharply divided depending on their region and industry segment. The prevailing mood is uncertainty. This is a new phenomenon.

The major undercurrent:
The auto business is not getting any easier and its growth is shifting from North America and Western Europe to Asia and Eastern Europe.

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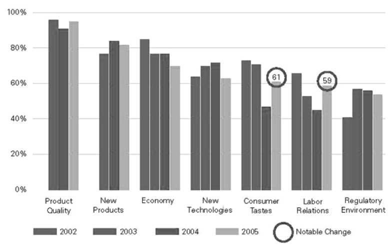
Notable Trends and Strong Perceptions

- Executives think Asian brands are by far the most likely to gain global market share, with South Korean and Chinese brands leading Japanese and Indian brands.
- The most important issue to auto executives is "product quality," with "reducing costs" a close second.
- Profitability expectations for the industry globally are dipping, with European and Asian executives now as gloomy or gloomier than their North American counterparts and executives of smaller suppliers more worried than those of big suppliers and vehicle manufacturers (VMs). Notable is a higher expectation of potential VM and supplier bankruptcy.
- In Asia, Asian brands are expected to be the most dominant over time, with non-Chinese Asian companies thought to be most likely to succeed in China.
- New manufacturing capacity will be added in Asia, South America, and Eastern Europe at the expense of North America and possibly Western Europe capacity.
- VMs are expected to be the most profitable segment, with captive finance companies right behind – but the latter are down sharply from two years ago.
- Global overcapacity: one in three think it is greater than 20 percent, up from one in five last year.
- The types of vehicles expected to make the biggest gains in market share will be small, inexpensive cars and gas/electric hybrids, both prized for fuel efficiency.
- Whereas sport utility vehicles (SUVs) are declining in popularity in the United States, they are growing in both Asia and Europe, particularly the less expensive, more fuel-efficient models. The same is true for minivans.
- Sales incentives are less of a differentiating issue—their use is so widespread that consumers have come to expect them.
- The main reason for investing in China continues to be selling to Chinese consumers rather than manufacturing for export.

Note: All charts in this document were provided by Applied Research & Consulting LLC.

Under the auspices of KPMG's Automotive practice, Applied Research & Consulting LLC (ARC) conducted 140 quantitative interviews with executives, 50 based in North America and 90 based in Europe and Asia. Of these, 105 worked for suppliers and 35 for vehicle manufacturers.

Importance of Key Industry Issues



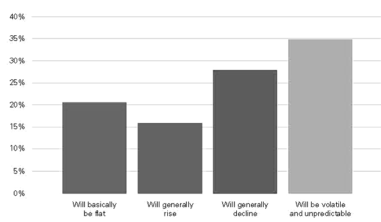
Top Issues: Quality and Consumer Tastes

Overall, the spread between most important and least important issues has narrowed somewhat, with the lowest gaining. This result underscores one of the year's main themes: executives are less certain about the future.

Specifically, for the third year running "product quality" is the top issue in respondents' minds (95 percent), followed by "new products" (82 percent), the perennial number two issue since 2003. Third was "the economy" (70 percent), falling for the third time in four years from its 2002 high of 85 percent.

Other significant changes include a rebound in the importance of "consumer tastes" (61 percent) after a sharp fall between 2003 and 2004 from 71 percent to 47 percent. Also, "labor relations" bounced back from 45 percent to 59 percent, its second-highest rating in four years, perhaps as manufacturers and suppliers have started to obtain some healthcare benefits concessions from their unions.

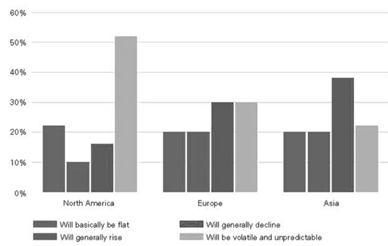
Profitability Expectations over the Next Five Years



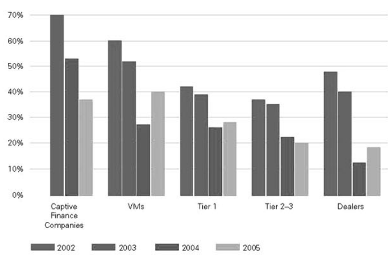
Profitability Concerns

Record high sales incentives, quarterly losses of historic proportions, and the continued transfer of market share from Detroit to Tokyo and Seoul, among other factors, appear to weigh on respondents as they contemplate the global industry's ability to generate profits over the next five years. Of four possible responses about future profitability, the largest number (35 percent) selected "volatile and unpredictable," with "generally decline" second at 28 percent, and "basically flat" third with 21 percent. The smallest number, 16 percent, thinks profits will "generally rise." When those who opt out by choosing "volatile and unpredictable" are removed, "generally decline" is 43 percent, "basically flat" is 32 percent, and "generally rise" 25 percent. Clearly, the highly charged competitive atmosphere and the pressure to cut costs are having an impact.

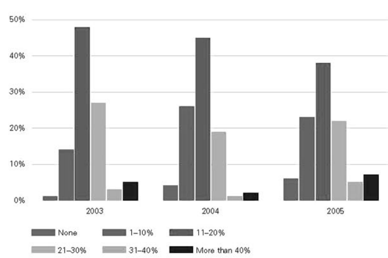
Profitability Expectations over the Next Five Years by Continent



Profitability Expectations over the Next Five Years by Company Type



Levels of Production Overcapacity

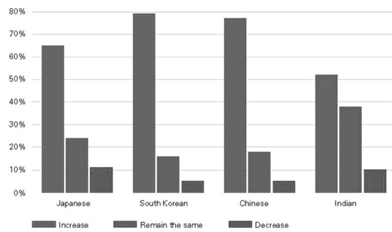


Interestingly, the most pessimistic are VM executives, 46 percent of whom chose “generally decline” while those who expect little change are Tier 1 respondents, 36 percent of which selected “basically flat” profitability over the next five years. The results differ by region. Asians are the most pessimistic, and almost half – 49 percent – expect that profits will “generally decline.” The “basically flat” camp includes far more North Americans (46 percent) than Europeans (29 percent) or Asians (26 percent). The optimists who think profits will rise include slightly more Europeans (29 percent) than Asians (26 percent) or North Americans (21 percent).

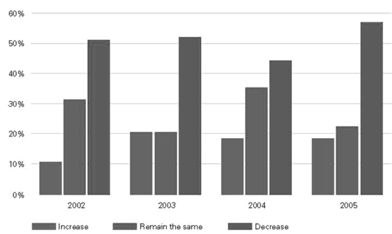
The perception of which segments will be most profitable has changed considerably over four years. VMs were thought to be the most profitable (61 percent) in 2002, followed by dealers (49 percent). When “captive finance companies” was added as a category in 2003, it shot to the lead (70 percent) but has fallen rather precipitously since, registering just 38 percent this year, most likely reflecting the growing cost of money and the increasing use of sales incentives throughout the industry. VMs are at the top again this year (41 percent), bouncing off a quite low level of 28 percent last year. But perhaps the most salient trend over the past three years is the downward moving average of the industry as a whole: expectations for future profits are clearly falling almost everywhere in the car business, with the exception this year of original equipment manufacturers.

There is a slight rise in respondents’ sense of the industry’s global overcapacity from last year – or, more precisely, a shift toward higher overcapacity. In 2004, 22 percent thought overcapacity was 21 percent or higher with 45 percent estimating 11 percent to 20 percent. This year 34 percent of executives think overcapacity is 21 percent or higher. This small change reflects the industry’s long-standing sense of overcapacity in North America, compounded by the growth of capacity in Asia.

Asian Brands Most Likely to Increase Market Share



Expectations for North American Brands



Globalization to Continue

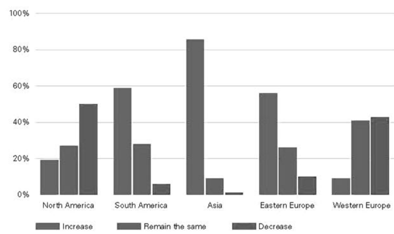
The major trend when looking at the car business globally is a significant transfer of manufacturing – and profits – from North America and Western Europe to Asia and, to a lesser extent, Eastern Europe. Specifically, almost nine in ten respondents (86 percent) strongly agree that "cross-border activity, such as partnerships, manufacturing, sourcing, and other transactions" over the next five years "will increase." Notes one North American Tier 1 executive, "The chief opportunity for the automotive industry is global expansion." And the heart of that opportunity, many executives believe, is Asia and specifically China: 86 percent of respondents think Asian consumers will be "a major source of growth" for the industry over the next five years.

However, this growth will be enjoyed disproportionately, the survey finds. Only 19 percent say North American brands will increase their global market share over the next five years and 58 percent say these brands will lose market share. Asian brands, on the other hand, are expected to increase market share according to a near unanimity among respondents (88 percent). Expectations for European brands are middling, with 34 percent expecting an increase, 38 percent expecting no change, and 28 percent expecting a decline in market share.

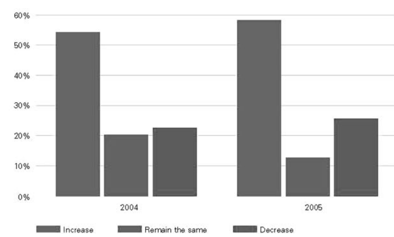
By country, all Asian brands will grow in global market share over the next five years, executives think, with South Korean (79 percent) and Chinese (77 percent) brands leading, followed by Japanese (65 percent) and Indian (52 percent) brands.

Can North American brands make headway by means of increased efficiency and competitiveness? Yes, said 56 percent of respondents four years ago. That perception has been steadily eroding: this year its adherents have shrunk to 32 percent.

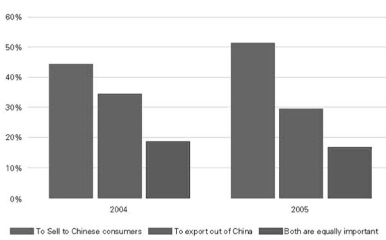
Growth in New Plants by Region over the Next Five Years



Profit Expectations for Investment in China



Drivers of Investment in China



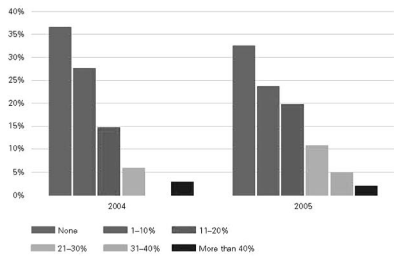
Likewise, respondents think manufacturing will flow out of mature economies into strong-growth regions. Nearly nine of ten respondents (86 percent) expect new plants in Asia over the next five years, 59 percent look for new South American plants, and 56 percent for new plants in Eastern Europe. By contrast, exactly half expect manufacturing to decline in North America and a slightly smaller number (43 percent) expect fewer plants in Western Europe by 2010.

The China Phenomenon Intensifies

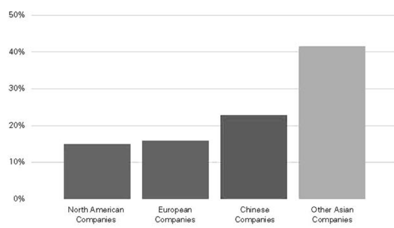
Despite the woes of rapid growth in the world's most populous country, executives increasingly believe China is the bright star in the industry's future. They also see complications.

Investment in China is full speed ahead – 83 percent think it will actually increase over the next five years. But there is a change in the "why and what" toward growth of the Chinese middle class. China will continue to be a magnet for low-cost outsourcing, but two new notions are emerging: China as a huge consumer market for vehicles and China as a global export threat – for both non-Chinese and eventually Chinese brands. Notes a North American Tier 2 executive, one of "the most important trends in the automotive industry today is the rise of China as a producer and potential exporter."

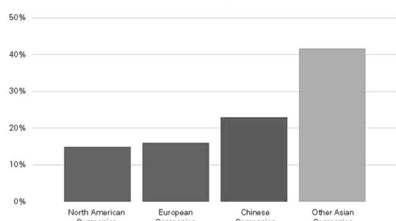
Concerns About Chinese Overcapacity Grow Slightly



Companies Best Poised in China



Non-Chinese Asian Companies Best Poised in China



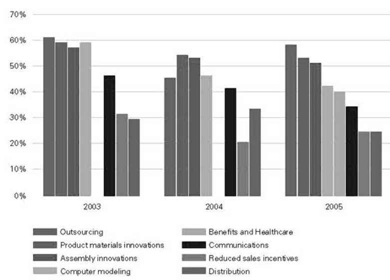
But executives are fine-tuning their expectations about China. For example, from last year to this, those pointing to Chinese consumers as the primary reason to invest there rose from 45 percent to 52 percent, while those thinking about exporting out of China fell from 35 percent to 30 percent.

Profits are a big reason China is so attractive for investors, and 59 percent of respondents think profitability from Chinese operations will increase over the next five years, up slightly from last year's 55 percent. About one in four respondents (26 percent) thinks profitability in China will decrease, essentially unchanged since last year.

However, fears of overcapacity in China are rising. Last year 52 percent thought there was some overcapacity; this year the figure rose to 62 percent. Those who believe there is more than 10 percent overcapacity rose from 24 percent last year to 38 percent in 2005. But while a majority of respondents continue to think the total number of foreign VMs in China will shrink over the next five years, those who believe seven or more will remain rose since the last survey from 32 percent to 38 percent.

Interestingly, 42 percent say the surviving companies will most likely be non-Chinese Asian ones, such as South Korean and Japanese firms. Just 15 percent say they will be North American, 16 percent say European, and 23 percent say native Chinese companies will be most successful.

Major Opportunities for Cost Savings



Cost Savings to Narrow

Overall, there is a slight decline in executives' expectations for the efficacy of future cost savings. "Outsourcing" leads the eight categories of "major opportunities" for future cost savings with 59 percent of respondents, rebounding from last year's drop to 46 percent from the previous year's 62 percent. Last year's result might be explained by the fact that it was an election year and talk of job losses as a result of outsourcing was a decidedly unpopular topic.

The second and third major opportunities for cost savings this year, "product materials innovations" (54 percent) and "assembly innovations" (52 percent), have been among the top three or four in respondents' choices three years running.

In a separate question, and reinforcing this shift, the percentage of respondents who think the new product development cycle will decrease dramatically over the next five years declined abruptly this year from 63 percent in 2004 to 48 percent.

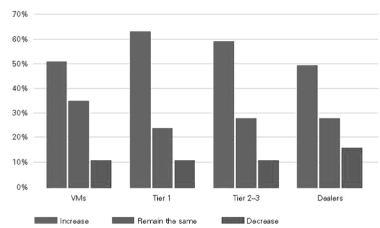
A new potential cost-saving category this year, "benefits and healthcare," found 41 percent of executives thinking future cost savings will result from these areas – not surprising given the strong pressure the industry is placing on auto unions and retirees to reduce the overall size of healthcare and retirement benefits.

The category "communications," which includes efficiencies provided by information technology and the Internet, is down this year to 35 percent from a high in 2003 of 47 percent – again, like "computer modeling," most likely because executives see this area as established in company operations, not an innovation that will move them forward at the expense of competitors.

"Distribution," which includes dealer bodies, remains an area of low expectations among executives for cost savings, though the sharp drop from last year – 34 percent to 25 percent – is notable. Anticipation of a soft last third of the year, with dealers having to shoulder their part of the burden, surely influenced responses.

"Sales incentives," meanwhile, finished last among all cost-reduction options, with just one in four of those surveyed feeling they will produce cost savings, though this is up slightly from last year's 21 percent. (In 2003 the result was 30 percent.) Quite clearly, a large plurality of auto executives continue to think sales incentives are embedded in how the auto industry and consumers interact, and they have become an industry norm.

Consolidation Expected Across the Value Chain



Consolidation Looks Mixed

One response to overcapacity and constrained profitability is consolidation, and the survey has tried to probe industry sentiment in this area for three years. Overall, executives expect consolidation to be most active in Asia (76 percent) and least active in Western Europe (38 percent), with North America (51 percent) and Eastern Europe (56 percent) roughly equivalent.

Uncertainty rules expectations about North American consolidation when viewed through a three-year lens. The years 2003 and 2005 are roughly the same, with majorities expecting an increase in consolidation (50 percent and 51 percent), but last year that number dropped to 39 percent and those who thought the situation would stay the same over five years rose to 51 percent from 35 percent – and is at 32 percent this year. (Those who think consolidation in the North American auto business will decrease are few – 8 percent in 2003 and 2004, rising to 14 percent in 2005.) Why 2004 was so different is not clear, but surely an improving economy and growth prospects in China were factors.

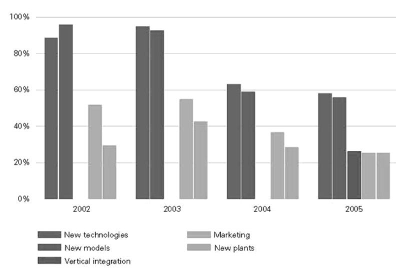
Where will consolidation happen? A significant move has occurred since last year: The majority of executives still target Tier 1 and Tier 2 suppliers for consolidation, with a slight rise for both Tier 1 (56 percent to 63 percent) and dealers (44 percent to 49 percent), but VMs shot up to 51 percent from 35 percent last year. Also note that last year 47 percent thought things would stay the same for VMs, but this year only 35 percent predict no change in consolidation activities.

The reasons for strategic realignments this year more strongly favor negative over positive opportunities, with "cost pressures" leading, up more than ten points from 62 percent to 73 percent, followed by "lack of profitability" (59 percent) and a host of potential causes all in the mid-forties, including: "access to new markets," "potential synergies," "poor financial performance," and "risk of bankruptcy." Trailing all are "global economic recovery" (38 percent, up from 28 percent last year) and "regional economic recovery" (26 percent), indicating that executives are by no means confident that good economic news will spur consolidation, but that recovery on a global scale is a bit more likely to do so. Also, for the third consecutive year, slightly more than half of the respondents think "cooperative ventures will be more important than mergers and acquisitions in the auto industry" over the next five years, again indicating that the industry continues to feel averse to risk.

Where to Invest?

As a further sign of industry wariness, only two areas – "new models" and "new technologies" – are thought by a majority to enjoy increased investment over the next five years. In 2002 and 2003 "marketing" was also embraced by a majority. More significantly, in 2003 nine of ten expected increased investment in "new models" and "new technologies"; this year only five of ten were confident of increased investment in these areas over the next five years, down from six of ten last year. Only one of four expects investment levels to increase in "vertical integration," "marketing," or "new plants." The industry appears to be narrowing its options and hunkering down.

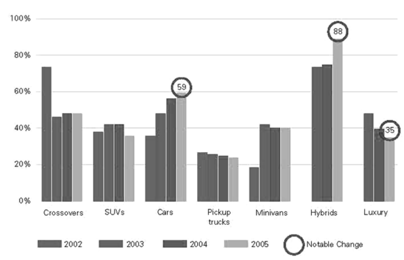
Areas of Increased Investment



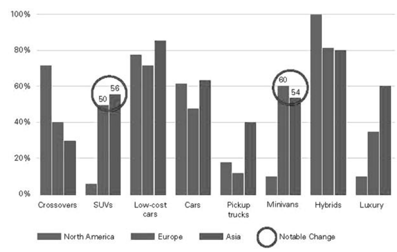
Model Array in Big Churn-Up

A major shift looks to be under way in the mix of vehicle types in North America. And while it might not yet be readily apparent on highways and in driveways, it soon will be. Notes an executive at a North American VM, "The most popular trends are restyling and having cars be more economic, and having fewer big cars." Echoes a North American Tier 2 executive, "I think the trend is a shift away from SUVs and pickups to higher quality small and mid-size cars." Recent sales figures in North America certainly bear out these observations, at least over the short term.

Change in Market Share by Type of Vehicle



Change in Market Share by Type of Vehicle by Region



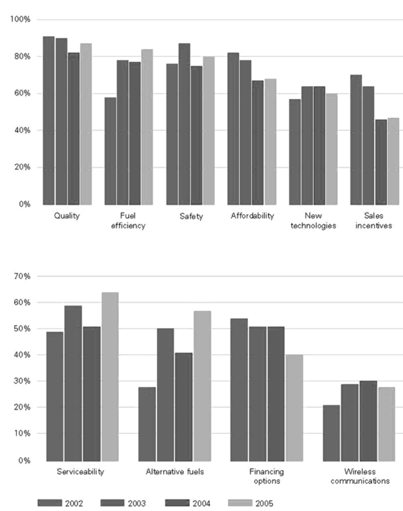
With fuel prices high and likely to stay there, if not increase (although prices have fallen in the past three months), one North American VM executive said, "We will expect US$100 per barrel in the future." It is not surprising that the two categories of vehicles respondents think most likely to gain market share are hybrids (up this year from 74 percent to 88 percent) and a new category for 2005, low-cost cars (79 percent). Cars also rose slightly (to 59 percent from 56 percent), while SUVs fell from 42 percent to 36 percent and luxury vehicles dropped from 40 percent to 35 percent – just two years ago "luxury" received 48 percent. Three categories were steady year to year: crossovers (48 percent), minivans (40 percent), and pickups with the lowest figure at 24 percent.

Several of the regional variations are startling. You would expect executives around the world to think low-cost cars will gain global market share over the next five years, and they do. They also support growth in hybrids, though 100 percent of North Americans foresee hybrid expansion – the first 100 percent reading in the survey's four-year history – while four of five Asians and Europeans agree.

The third highest prospect for growth among North American respondents is crossovers (72 percent), but the category ranks much lower for Europeans (40 percent) and Asians (30 percent). It seems likely the concept simply has yet to catch on in those markets – that North Americans are ahead of the curve. Several other categories suggest this may be the case. Both Asian and European executives see strong growth for SUVs (56 percent and 50 percent, respectively), but just 6 percent of their North American counterparts agree. A similar scenario holds for minivans, with 60 percent of European and 54 percent of Asian executives expecting the category to grow, but just 10 percent of North American executives agreeing. "Luxury vehicles" is much more likely to be seen by Asian respondents as a growth category (60 percent) than Europeans (35 percent), while North Americans are downright pessimistic about growth in luxury brands (10 percent). Cars, excluding the low and high ends, are third among Asian respondents (64 percent), fourth among North Americans (62 percent), and fifth among Europeans (48 percent). Only Asian respondents see much growth in pickups (40 percent); just 18 percent of North Americans and 12 percent of Europeans agreed. Once a statement of success and status, the accessorized pickup may have lost its power to enhance – to the woe of manufacturers, which built them on long-amortized assembly lines and basked in large profit margins.

To sum up, among North American executives, the days of robust SUV, pickup, and luxury vehicle sales growth are over. They think the emerging world will look quite different, populated by crossovers, small cars, family sedans, and hybrids. The shift is not quite so apparent to European executives, who still see healthy growth in SUVs and minivans, two categories that are in the early stages of their sales cycles on the continent. Asian executives, by contrast, expect significant to strong growth in every category, reflecting the region's general optimism about market conditions over the next five years.

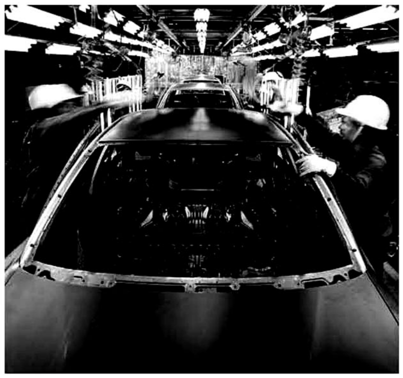
Consumer Purchase Criteria



The Industry's Take on Buyers' Wants and Needs

"Fuel efficiency" has risen to the second spot in consumer purchase criteria, in executives' minds, with 84 percent feeling strongly that car buyers want fuel-efficient vehicles. In 2002 that figure was 58 percent. In a related question in 2003, 43 percent said there will be a "major increase" in U.S. sales of alternative-fuel or hybrid cars; in 2005 that number jumps to 68 percent. And in just one year the number of respondents who think consumer acceptance of hybrids will increase climbed from 54 percent to 74 percent – a sizable if not remarkable increase.

"Safety" remains high in consumer importance, executives believe – it ranks third with 80 percent. Meanwhile, "affordability" as a criterion has fallen from a high of 82 percent in 2002 to 68 percent this year, equal with "design" (a new category) and just above "serviceability," which jumped to 64 percent from 51 percent last year. "New technologies" slipped slightly from 64 percent to 60 percent this year. "Alternative fuels" also rose substantially this year, from 41 percent to 57 percent. In 2002 alternative fuels as a criterion was second to last at just 28 percent. "Sales incentives" held steady in the third from last spot at 47



percent; but the number was 70 percent in 2002 and 64 percent in 2003, indicating once again that executives do not believe incentives are all that persuasive when it comes to the buy/no-buy decision. Reinforcing this notion, "financing options" dropped from 51 percent to 40 percent this year and into second to last place, ahead of "wireless communications."

While there are some constants in the industry's perceptions of consumer purchase criteria over the lifetime of this survey – quality, safety, new technologies – upward shifts in "fuel efficiency," "serviceability," and "alternative fuels" indicate an awakening that fuel prices and maintenance costs are weighing on car buyers. A more practical, less self-indulgent era may be dawning. That the issues of "affordability," "sales incentives," and "financing options" have all fallen probably says that shoppers, executives believe, are able to purchase the vehicles they want once they have made the decision to buy. Incentives and the array of financing choices, the latter made vastly more available and easier to obtain thanks to the Internet, are now just the way of the world.

Fraud and Ethics Concerns

For the first time, the survey asked respondents several questions to determine the industry's mood about fraud and ethics issues. Only 35 percent feel that the "effectiveness of anti-fraud programs and controls" for auto companies "has increased in the past 12 months." And 47 percent strongly agree that companies will spend more to "help combat fraud and misconduct" over the next five years. Also, 68 percent agree that the focus on "corporate governance, ethics, and compliance" will increase, with North American and Asian executives significantly more likely to agree than their European counterparts.

The greatest risks to companies in these areas, respondents feel, will come from "security of intellectual property" (26 percent), followed by "financial reporting fraud" (24 percent) and "vendor-related/third-party fraud" (22 percent). However, European executives feel "violation of laws and government regulations" are more likely to pose the greatest risk (30 percent) than do North American and Asian executives.

Captive Finance on the Wane

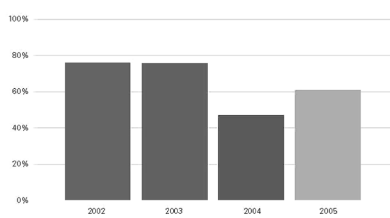
Also new this year is a series of questions probing the captive finance area, recently a major source of revenue and profits for car companies, but suffering from diminishing expectations over the past three years. In 2003, 70 percent of respondents thought captive finance arms would be by far the most profitable industry segment over the next five years, compared with 53 percent for VMs. But that number declined to 54 percent in 2004, still ahead of VMs (28 percent) and Tier 1 suppliers (27 percent). This year, captive finance arms trail VMs slightly in profitability expectations, though not in statistic value (38 percent to 41 percent for VMs).

To grow over the next year, half of the respondents feel, captive finance companies will make "the most of their strategic investments" overseas, while two of five cite increased spending on "customer relationship management." Only one of ten cites "back-office technology."

Over the next year, respondents think, "consumer regulatory compliance" will be the top risk management initiative for captive finance companies (39 percent), followed by "privacy" (33 percent), anti-money-laundering (21 percent), and the new capital standards spelled out by Basel II (7 percent).

Rebound in Electronics

(Percentage of a Car's Value Coming from Electronic Components)



Conclusion: How to Capitalize on a Fundamental Shift

Just as the survey results were being gathered this year, two momentous events occurred: one of the world's largest automotive suppliers declared bankruptcy and the world's biggest auto company said it would cut 30,000 jobs and close up to a dozen plants.

The survey predicted the first result. A new question asked if any VMs or big suppliers would file for bankruptcy in the next few years – 76 percent said "yes." Will another shoe drop? Respondents' answers on a range of issues make that seem likely.

A fundamental shift is occurring. Growth prospects are no longer exciting in the established industrial powerhouses of North America and Europe, with the possible exception of Eastern Europe – China is the darling of the global car industry. And car sales in India are taking off. Yet the strong growth in China of late is calming. And expectations for the industry's future profitability growth around the world are low, even in China. One worry is overcapacity. Another is an almost palpable resignation that sales incentives and low-cost financing options have become routine. A third reason is revealed in expected changes in the model mix: the future is largely about low-margin products, small cars and hybrids, and family sedans. Without high-margin SUVs and pickups and luxury cars, where will profits be found?

One place may be electronics, which rebounded this year: 61 percent say the percentage of a vehicle's value from electronics "will increase dramatically." (It was 47 percent last year, 76 percent in 2002 and 2003.) Another may be fuel-efficiency measures that are less costly than full-blown electric-gas hybrids, such as diesel engines. A third will surely be the growing use of shared vehicle platforms coupled with thrilling designs and impressive build quality. But cost cutting does not appear to be a very promising path to profitability, though outsourcing is back in favor. Rarely do more than half of respondents feel strongly that any of the eight broad areas of potential cost savings is a "great…opportunity."

Clearly, the hard work of making cars and trucks that consumers hunger for and feel happy owning and driving is never ending. Building them efficiently has never been more important. But the increasingly global marketplace is not forgiving. Meeting regional wants and needs with global planning and efficiencies is the path successful companies should aim to take to profit in the future automobile business.

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