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FUTURE OF THE HYDROGEN FUEL CELL

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED EIGHTH CONGRESS

FIRST SESSION

MAY 7, 2003

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SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED EIGHTH CONGRESS

FIRST SESSION

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FUTURE OF THE HYDROGEN FUEL CELL

WEDNESDAY, MAY 7, 2003

U.S. SENATE,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Committee met, pursuant to notice, at 2:36 p.m. in room SR–253, Russell Senate Office Building, Hon. Sam Brownback, Chairman of the Subcommittee, presiding.

OPENING STATEMENT OF HON. SAM BROWNBACK, U.S. SENATOR FROM KANSAS

Senator BROWNBACK. The hearing will come to order. We're going to have a fun hearing today on a great topic, hydrogen-fueled automobiles and other uses of hydrogen fuel.

I'd like to begin the hearing of the Science, Technology, and Space Subcommittee by thanking each of our witnesses. I appreciate you coming today. I want to thank you on behalf of the Committee for joining us here today and sharing your testimony. Secondly, I want to thank you on behalf of my kids for your leadership in advancing the practical applications of hydrogen fuel cell research. This is an incredibly important issue for the future, and it certainly has a lot of excitement and interest for now and for the next generation.

Perhaps a critical duty for any leader, whether you're a CEO, Secretary of State, a principal of a high school, is to advance a vision of what we want our country and the world to look like. As did countless generations before we were born, we are charged to leave our children's life better than that which we inherited. I'd also argue that this notion of the world we would like to leave our children is a vision that unites us. While we often disagree about how to get there, we just as often agree about where we would like to be heading.

It is almost universally held we would like to be energy independent. This country is best when it is a forceful advocate for democracy and freedom. Unfortunately, far too often, our Nation's interests in advancing these principles stumble over our interest in affordable and reliable sources of energy. It is a generally held belief that the more affordable and reliable energy sources we can develop at home, the more freely we will be able to advance American ideals abroad.

Generally, I think we can all agree that we would like to leave our children a cleaner, better environment. My dad is a farmer in Parker, Kansas, and he farms the land that his dad farmed. My brother farms the same land. Growing up on a farm, you can't help but learn the values of good stewardship. I have no doubt that Dad is going to leave to my brother, Jim, the land better than he found it.

I've been very blessed to see a great deal of this country, and I have a great faith that we are living on a gift from God. As stewards of this country, such is our responsibility to pass on the gift to the next generation in better condition than it was received.

But we can't ignore that we are also stewards of the economy. If we listen to the debate around here, it's very clear that we agree that a robust economy makes this country strong. Again, we don't all agree on how to get there, but I suspect that that's a whole different hearing. We have a tremendous burden to keep the economy growing and to continue creating new jobs.

If the duty of a leader is to advance a vision of the future, perhaps the greatest trick of leadership is not having to sacrifice one goal for the sake of another. And therein lies the importance of the hydrogen fuel cell.

Hydrogen is the most plentiful element on the planet. Two-thirds of the planet is water. Two-thirds of water is hydrogen. Now, I'm trained neither as a scientist, nor an engineer, but as near as I can figure, we have all the hydrogen that we need right here within our borders.

As for the environment, at worst the emissions of a hydrogen fuel cell is minimal, and the efficiency of fuel cells is unmatched by conventional technologies. Likely, the initial generations of fuel cells will rely on some form of petrochemicals, most likely natural gas, to produce the hydrogen. However, the modest amounts of CO2 emitted from these power sources are dwarfed by the emissions of today's cleanest internal combustion engines.

In addition, today's internal combustion engine captures only 15 to 20 percent of the energy in gasoline. Fuel cells, on the other hand, convert 40 to 65 percent of hydrogen energy into electricity. The potential of this 160-year-old technology to help us achieve cleaner air by the time my kids are driving their kids to school is staggering.

Not only can our economy be sustained in a transition to a greater reliance on hydrogen, but our economy can grow as we move toward hydrogen. As we have seen in the past several years, our economy is extremely sensitive to fluctuations in energy cost. Moving away from the more limited and unstable commodities of fossil fuels towards the more abundant hydrogen has a tremendous potential to insulate the economy from fluctuations in energy prices.

In addition, where there is innovation, there is growth. As American companies, like those represented here today, develop the innovative technologies that carry us into hydrogen-based transportation and possibly a hydrogen-based economy, our country will see growth follow.

However, for all the potential of hydrogen fuel cells, to paraphrase Robert Frost, there are many miles before we sleep. The time frame we've laid out for the transition to hydrogen-based transportation is almost unmatched in human history. To meet the time frame, our commitment must be unwavering.

We thank those of you who are here to testify today, in advance, for all the hard work and the dedication and the leadership you will invest and have already invested in this mission. And that's why we look forward to your testimony and presentation and answering questions today.

We've been joined by another advocate of hydrogen technology that's approached me and talked with me on the floor about this issue and has aggressively supported it, Senator Dorgan, from North Dakota.

STATEMENT OF HON. BYRON L. DORGAN, U.S. SENATOR FROM NORTH DAKOTA

Senator DORGAN. Senator Brownback, thank you very much.

Let me just make a couple of comments before we begin the hearing. I will not be able to stay for the entire hearing, but I'm especially pleased that you're holding it, because I think this is the issue. We have the energy bill on the floor. It includes an initiative dealing with hydrogen and fuel cells. The President has indicated his interest and his administration's support for this. I have indicated previously that it is enormously welcome, because putting the administration's support behind this direction is not only a breath of fresh air, but is an enormous source of strength to move something like this through the Congress.

I've indicated also, without meaning to be highly critical, that the President's specific proposal was more timid than I would like. I had offered legislation here in the Congress prior to the President making his proposal, a more robust proposal that I think we ought to embrace. It is a $6.5 billion proposal over 10 years that sets targets and timetables of having 100,000 fuel cell vehicles on the road by 2010 and 2.5 million vehicles on the road by 2020.

This is not a project that will be achieved just because we wish it to be so. The issue of finding a new supply of energy, particularly hydrogen, means that we have issues dealing with the production, the transportation, the storage of hydrogen, and the continued development of increasingly sophisticated fuel cells.

But, as you indicated, Mr. Chairman, running gasoline through the carburetors of our vehicle fleet forever makes no sense to me. Fuel cells are twice as efficient as running gasoline through carburetors, in terms of putting power to the wheel, and it just makes sense to me, especially given what we've seen in Iraq and the Middle East recently, that our economy should not be so overly dependent on foreign sources of energy. The fastest growing part of our energy usage is in transportation, by far. We import 55 percent of our oil. Which is expected to increase to 68 percent by the year 2020. That's an unsustainable path, and it's a path that jeopardizes this country's economy. It holds our country hostage to conditions that we do not, cannot, and will not control.

We will continue to dig and drill, and we will continue to increase production of oil, coal, and natural gas. I support all that. But if digging and drilling is our only energy strategy, then we are confined to a "yesterday-forever" strategy.

Mr. Chairman, my first car was a 1924 Model-T Ford. I restored it as a young teenager. I put gasoline in the 1924 Ford the same way you put gasoline in a 2003 Ford. Not a thing has changed in a century. The new dream and vision of a hydrogen economy with fuel cells, particularly for our transportation fleet, but also stationary fuel cells, is something that can cause fundamental change in this country that is positive—positive for our economy, and positive to help us become less dependent on things that we can't control. I just think that this requires a robust, aggressive push from all of us in public policy.

I'm really pleased with the people you have testifying. I've worked with many of them. Mr. Garman has been to North Dakota. We've talked about other energy, wind energy. But Mr. Garman, I know that you are representing the administration's view of how much we can do, and you and I have a slight disagreement about how aggressive we can or should move. But we have no disagreement on the direction, and that is refreshing to me. This administration has put itself in the position of saying, "Let's move in this direction." I say, "You bet. Let's do it, and let's be very bold about it as we do it."

My hope, Mr. Chairman, is that when the energy bill leaves the Senate, even though we nearly tripled the amount of effort in the Energy Committee on the hydrogen piece—we're up to a little over $3 billion at this point—my hope is that we can increase it even more so that my grandchildren and your grandchildren, when they turn the key in their vehicle, will be turning their key in a fuel cell vehicle that uses hydrogen.

And if I can make one final point. Secretary Garman came to North Dakota to talk about wind energy. There is a wind energy component in this, as well, because wind blows intermittently. But you put up the new efficient wind turbines to produce electricity and use electricity through the process of electrolysis to separate hydrogen and oxygen for water, store the hydrogen, and use it for our vehicle fleet. It all fits together in a wonderful, wonderful way, and because of that, I sleep better. It was therapeutic to say all of this.

[Laughter.]

Senator DORGAN. Thank you.

Senator BROWNBACK. Thank you very much, Senator Dorgan, whose passionate support of hydrogen is obvious.

Senator Lautenberg, do you have an opening statement?

STATEMENT OF HON. FRANK LAUTENBERG, U.S. SENATOR FROM NEW JERSEY

Senator LAUTENBERG. Thanks, Mr. Chairman. I listened with interest to Senator Dorgan's statement, and he talked about fixing up his 1924 vehicle. I had a energy-less vehicle in 1924. It was my mother pushing me in a baby carriage, and——

[Laughter.]

Senator LAUTENBERG.—you can't find that kind of energy around anymore, but I didn't realize that you were old enough to understand that. I'm pleased to be here, also, to join in this discussion, this review of where we go beside fossil fuels and how we get where we want to go. And I'm not talking about the mileage alone. The alternatives have to be found to the way we do business today.

It's so rare that we hear things like "conserve" or "sacrifice" or things of that nature, and I think the best way to get where we'd like to be is to really devote our energy and our resource to this opportunity with the hydrogen fuel cells. And I just passed a car that's parked outside downstairs that General Motors is showing, a hydrogen fuel cell car. But it's still prototype. It's not ready at all for production. But they are going into hybrid production, I was told, next year. And that will add something like a 10 percent efficiency factor. If that translates immediately to the use of oil, to the importation of oil—I mean, the numbers are staggering.

Well, in the State of the Union Address, President Bush announced a new $1.2 billion dollar research and development initiative for hydrogen-fueled vehicles. Now, as those in this room know now, the hydrogen fuel cells hold enormous promise as an efficient low-emission source of power. And theoretically, it's possible to create a hydrogen fuel cell that only emits water, and the water can be used again as a source for more hydrogen.

The President's initiative is meant to complement the Department of Energy's Freedom CAR Program, a 2-year-old cooperative research program between the Federal Government and universities and private industry. But as important as hydrogen will be down the road, I can't help but think that the initiative merely scratches the surface. It's designed to, I think, hide the relatively poor record that we've had with regard to cutting auto emissions and our dependence on OPEC oil now at a time when we know how precarious that supply is and the availability.

The fastest, cheapest way to cut our dependence on foreign oil now is to make our cars and trucks go further on each gallon of gas that they burn. And the fact is, the automakers are keenly aware of hydrogen promises and are investing $2- to $3 billion of their own money each year to develop the technology. And the Federal Government's money, $1.2 billion, would be better spent promoting near-term fuel economy improvements in our cars and trucks. And this near-term component is what's missing from the President's approach.

According to the National Academy of Sciences, existing technologies could be used to raise fuel efficiency to 40 miles per gallon without compromising safety. The NRDC estimates that we could cut the amount of oil our cars and trucks use by a half by the year 2020, and by three-quarters over the next three decades, compared with business-as-usual projections. And total consumer savings from these improvements would equal nearly $13 billion per year in 2012, and almost $30 billion by 2020.

By lifting the fuel economy standards for the national fleet to 40 miles per gallon by 2012 and 55 miles per gallon in 2020, we'd save nearly 4 billion barrels of oil over the next dozen years. And by the year 2012, we could save nearly, it's believed with credibility, 2 million barrels each day. That's more oil than we imported from Saudi Arabia last year, and three times our imports from Iraq. By 2020, savings would grow to nearly 5 million barrels a day, which is almost twice the amount that we currently import from the Persian Gulf.

When it comes to hydrogen, I'm anxious to learn more from the witnesses today about this exciting technology, how long it'll take before hydrogen-fueled cars and trucks are commercially feasible. But I would suggest that we should also hold a hearing, Mr. Chairman, on why President Bush hasn't announced any initiatives to cut auto emissions and our dependence on OPEC oil now.

And I look forward to hearing from our witnesses, and I thank you, Mr. Chairman, for holding this meeting.

Senator BROWNBACK. Yes, thank you, Senator Lautenberg.

We have two panels today. Our first panel is the Honorable John Marburger III. He's director of Office of Science and Technology Policy. And the Honorable David Garman, Assistant Secretary for Energy Efficiency and Renewable Energy of the U.S. Department of Energy.

Gentlemen, we're delighted to have you here today, delighted to hear your testimony, and look forward to that and answering questions.

And, Mr. Marburger, if you'd be willing to go first, if that would be all right. We will put your full statement into the record as if presented, so you're free to summarize if you'd like.

STATEMENT OF HON. JOHN H. MARBURGER III, DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY

Mr. MARBURGER. Thank you Mr. Chairman, Senator Dorgan, and Senator Lautenberg. It's a pleasure to be here. I appreciate the opportunity to appear before you today to discuss the President's hydrogen fuel initiative. I will keep my oral presentation short so there's time for questions, and I appreciate that my written testimony will be included in the record.

The President's National Energy Policy Report that was released 2 years ago this month set forth a vision for a clean, secure, and affordable energy future. That vision includes a key role for hydrogen as an energy medium across the entire spectrum of energy applications.

President Bush, as you noted, emphasized in his State of the Union Address this year that one of his chief domestic goals is to promote energy independence for our country while dramatically improving the environment.

Senator BROWNBACK. Mr. Marburger, could you pull that microphone closer to you? I don't know if it's picking up very well.

Mr. MARBURGER. Okay.

Senator BROWNBACK. There you go.

Mr. MARBURGER. The President subsequently announced the Hydrogen Fuel Initiative to develop the technology to enable mass production of clean hydrogen-powered automobiles and the infrastructure to support them by 2020. The Hydrogen Fuel Initiative complements the previously announced Freedom CAR Partnership, which includes fuel cell, hybrid electric, and other advanced automotive technology research.

Other new initiatives have followed, including the Carbon Sequestration International Leadership Forum, the FutureGEN Zero Emission Coal-Fired Electricity and Hydrogen Power Plant Initiative, and an international partnership for the hydrogen economy. In a related but much longer-term initiative, the President announced U.S. participation in the international collaboration on fusion energy research.

Hydrogen is important, because it can serve as a primary energy carrier. Like electricity, it can be produced from many different domestically available energy sources using technologies that do not emit pollutants or carbon dioxide. Furthermore, hydrogen-based transportation, power, and heating systems promise dramatic efficiency gains with greatly reduced noxious air pollutants and greenhouse gas emissions. These technologies, together with the other elements of the President's energy plan, have the long-term potential to substantially reduce or eliminate our Nation's dependence on foreign oil while improving the environment.

Our transportation sector, for example, runs almost exclusively on oil and we are importing more than half of our oil needs every day. Hydrogen can be produced from diverse domestic energy sources, including natural gas, coal, or nuclear energy, or biomass, wind, and solar power, anything that produces electricity. Although we will continue to strive for efficiency improvements in conventional vehicles, hydrogen-fueled vehicles can potentially remove petroleum from the equation altogether.

Hydrogen fuel cell vehicles are potentially more than twice as efficient as conventional cars and trucks. And if you consider the entire well-to-wheel energy cycle, including the efficiency of hydrogen production from natural gas, fuel cells still are more efficient and produce significantly less CO2 than conventional, diesel, or hybrid electric vehicles. Widespread use of fuel-cell-powered cars and trucks would also yield significant air quality improvements, particularly in urban areas.

As hydrogen production shifts toward newer energy source technologies, such as coal power with carbon sequestration or nuclear power, our transportation sector could reduce emissions of air pollutants and greenhouse gases to near zero.

So what do we have to do to achieve this hydrogen vision? There are significant technical challenges. First, we need a hydrogen infrastructure for convenient and affordable refueling of the vehicles and devices. The private sector builds infrastructure only when the business case is attractive. And considering that our current infrastructure delivers gasoline for less than the price of bottled water, this is a significant challenge.

When produced from natural gas, hydrogen is currently four times more expensive than gasoline. The President's Hydrogen Fuel Initiative proposes a large increase in R&D funding for technologies that will drive down the cost of production, storage, distribution, and delivery of hydrogen.

As the infrastructure develops, hydrogen will likely come from a number of different energy sources and production methods, as determined by the marketplace. The mix will depend on regional factors like the cost and availability of feed stocks or environmental constraints or state regulations. The hydrogen distribution and delivery systems will involve a combination of centralized production facilities, pipelines, local production of neighborhood fueling stations, and truck delivery to rural areas.

After the infrastructure challenge is the need for the fuel cell vehicles themselves to be cost competitive with the conventional vehicles that they will replace. Even in mass production, fuel cells today would be 10 times more expensive than comparable gasoline engines. Currently available high-performance fuel cells require relatively large amounts of precious metals, such as platinum, and highly engineered materials. Agency R&D efforts focus on reducing these costs and very promising new technologies are emerging.

A third challenge is the need for hydrogen storage systems with sufficient energy density to provide a 300-mile vehicle driving range without excessive size, weight, or cost. The President's initiative proposes funding increases for each of these vital research areas, along with the development of codes and standards that will foster safe handling and operation of hydrogen-fueled systems.

The hydrogen fission includes many other applications besides fuel cell vehicles. Stationary fuel cells can provide heating and power for buildings and reliable distributed power generation. As a hydrogen infrastructure is developed, local hydrogen production will support distributed power generation, and pipeline networks could serve residential applications.

This future-oriented initiative does not obviate the need for interim strategies to address our Nation's energy environmental challenges. The administration proposes to continue R&D in non-hydrogen transportation technologies—hybrid electric systems, for example—energy storage, and materials.

Our ultimate goal is a petroleum-free, emission-free energy future. The President's Hydrogen Fuel Initiative led by the Department of Energy proposes $1.2 billion for research over 5 years to overcome the key technology hurdles to enable a hydrogen-based economy. There are many other agencies involved in this initiative, including the Departments of Transportation, Defense, Commerce, Agriculture, NSF, NASA, and EPA, and my office will continue to work with all agencies, as usual, to assist coordination. The agencies, by the way, are working well together and have already begun to establish collaborative activities.

So I thank you very much for allowing me to present the President's initiative here today, and I'll be glad to answer questions.

[The prepared statement of Mr. Marburger follows:]

PREPARED STATEMENT OF HON. JOHN H. MARBURGER III, DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY

Mr. Chairman, Mr. Breaux, and Members of the Subcommittee, I appreciate the opportunity to appear before you today to discuss the President's Hydrogen Fuel Initiative.

America's energy challenges must be met with revolutionary new technologies and dedicated leadership to improve the production, distribution, and use of energy. The President's National Energy Policy Report, released in May 2001, establishes a clear path for our Nation to achieve a clean, secure, and affordable energy future. That vision includes hydrogen as an energy carrier in our automobiles, trucks, homes, and businesses.

In the State of the Union address in January 2003, President Bush stated that one of his key domestic goals is "to promote energy independence for our country, while dramatically improving the environment." The President then announced the Hydrogen Fuel Initiative to develop the technology to enable mass production of clean, hydrogen-powered automobiles, and the infrastructure to support them, by 2020. The Hydrogen Fuel Initiative complements the FreedomCAR partnership, which includes fuel-cell, hybrid-electric, and other advanced automotive technology research. Other new initiatives have followed from the President's leadership. In February, the Secretary of Energy announced the Carbon Sequestration International Leadership Forum, along with the "FutureGEN" initiative to build a zero-emission, coal-fired electricity and hydrogen power plant. Additionally, on February 3 the President announced that the U.S. will join Canada, the European Union, Japan, Russia, and the United Kingdom in the creation of an international collaboration on fusion energy research. Most recently, the Administration announced that it will lead an International Partnership for the Hydrogen Economy.

Through these initiatives, we will lead the effort, in concert with the private sector and other nations, to develop clean and secure energy supplies and energy systems. We envision a future in which hydrogen serves, along with electricity, as a primary energy carrier for the U.S. economy. Like electricity, hydrogen can be produced from a diversity of domestically available energy sources using technologies that do not emit pollutants or carbon dioxide. Furthermore, hydrogen-based transportation, power, and heating systems offer the promise of dramatic efficiency gains with greatly reduced noxious air pollutants and greenhouse gas emissions. These technologies, together with the other elements of the President's energy plan, have the long-term potential to substantially reduce or eliminate our Nation's dependence on foreign oil while improving the environment.

While we have made significant progress in reducing pollutant emissions from our cars, trucks, and power plants, and we will continue to make progress in the near term through ongoing regulatory actions, our objective is to move beyond the command-and-control mechanisms of environmental policy. We can do this by developing and deploying transportation systems and power systems that are emission-free by design.

For example, a hydrogen-based transportation sector would dramatically improve our Nation's energy security. Our transportation sector runs almost exclusively on oil, and we are importing more than half of our oil needs every day. Although we will continue to strive for efficiency improvements in conventional vehicles, hydrogen-fueled vehicles can potentially remove petroleum from the equation altogether. Hydrogen can be produced from diverse domestic energy sources, including natural gas, coal, nuclear energy, biomass, wind, and solar power. Upon successful market penetration, hydrogen fuel cell vehicles would dramatically reduce our dependence on imported oil, with ultra-clean hydrogen internal combustion engines as a possible interim step.

Hydrogen fuel cell vehicles offer the potential to achieve more than twice the efficiency of conventional cars and trucks. When considering the full energy cycle, including the efficiency of hydrogen production from natural gas, fuel cells are still more efficient—and produce less carbon dioxide—than conventional, diesel-powered, or hybrid-electric vehicles. Hydrogen fuel cell vehicles produce no emissions other than water. Widespread use of fuel-cell powered cars and trucks would thus yield significant air quality improvements, particularly in urban areas. As hydrogen production shifts more to renewable sources, nuclear power, and coal power with carbon sequestration, our transportation sector could reduce emissions of air pollutants and greenhouse gases to near zero.

In the State of the Union address, the President said:

> "With a new national commitment, our scientists and engineers will overcome obstacles to taking these cars from laboratory to showroom, so that the first car driven by a child born today could be powered by hydrogen, and pollution-free."

In order to achieve this hydrogen vision, we must overcome some significant technical challenges.

First, a hydrogen infrastructure must be built that will enable convenient and affordable refueling. The private sector will build the infrastructure only when the business case is attractive. Considering that our current gasoline infrastructure can deliver refined petroleum products to local stations for less than the price of bottled water, this represents a significant challenge. When produced from natural gas, hydrogen is currently four times as expensive to produce as gasoline. The President's Hydrogen Fuel Initiative, therefore, proposes a large increase in the research and development funding for technologies that will enable cost-competitive production, storage, distribution, and delivery of hydrogen. This includes funding for renewable- and nuclear-based hydrogen production.

As the infrastructure develops, hydrogen will likely be produced from a portfolio of energy sources and production methods, as determined by the marketplace. The optimal combination of energy sources will likely depend on regional factors such as the cost and availability of the feedstocks, environmental constraints, and state regulations. Similarly, hydrogen distribution and delivery systems will most likely involve a combination of centralized production facilities with pipelines, local production at neighborhood fueling stations, and truck delivery to rural areas.

Second, fuel cell vehicles must be safe, reliable, and cost-competitive with the conventional vehicles that they replace. Even in mass production, fuel cells today would be ten times more expensive than comparable gasoline engines. High-performance fuel cells require relatively large amounts of precious metals (platinum) and highly engineered materials. Agency research and development efforts are focused on reducing these costs.

Third, we must develop hydrogen storage systems with sufficient energy density to provide a 300-mile vehicle driving range without excessive size, weight, or cost.

The President's Initiative proposes funding increases for each of these vital research areas, along with the development of codes and standards that will help ensure the safe handling and operation of hydrogen-fueled systems.

The hydrogen vision includes many other applications besides fuel cell vehicles. Stationary fuel cells can provide heating and power for buildings and reliable, distributed power generation. Portable power units, laptops, and cell phones can also be powered by hydrogen. Some of these applications could achieve commercial viability before fuel cell vehicles do. As the hydrogen infrastructure is developed, local hydrogen production will support distributed power generation, and pipeline networks could serve residential applications.

In addition, as we work to achieve the hydrogen vision, we need interim strategies to address our Nation's energy and environmental challenges. Therefore, the Administration has proposed a continuing research and development effort in non-hydrogen transportation technologies such as hybrid-electric systems, energy storage, and materials. These technologies are expected to provide fuel savings both in the near term, by application to conventional gasoline-fueled vehicles, and in the long term by enabling commercially viable fuel-cell vehicles, which will need lightweight materials, high-density power electronics, and cost-effective energy storage devices.

Our ultimate goal is a petroleum-free, emission-free energy future. The President's Hydrogen Fuel Initiative, led by the Department of Energy (DOE), proposes $1.2 billion for research over five years (including $181.7 million in the FY2004 budget request) to overcome the key technology hurdles to enable a hydrogen-based economy.

Other agencies besides DOE, including the Department of Transportation (DOT), Environmental Protection Agency, Department of Defense, Department of Commerce, National Science Foundation, Department of Agriculture, National Aeronautics and Space Administration, and others, also conduct or plan to conduct significant research related to hydrogen and fuel cell technologies. For example, DOT will develop many of the codes and standards related to hydrogen technologies. In order to foster coordination across the federal government, and to improve the effectiveness of hydrogen research and development, my office is leading an interagency hydrogen R&D task force. The agencies have strongly supported this effort and have begun to establish collaborative activities. The task force will also provide an opportunity to reach out to the private sector and to expand coordination of research, where appropriate, to other nations through the International Partnership for the Hydrogen Economy.

The hydrogen vision is ambitious, but through the President's Hydrogen Fuel Initiative, together with related activities across the federal government, we can make substantial progress towards the vital, national goals of energy security and environmental stewardship.

I would be happy to answer any questions you may have.

Senator BROWNBACK. Thank you, Mr. Marburger, for the presentation, and I look forward to the questions back and forth.

Mr. Garman, welcome to the Committee, and I look forward to your presentation.

STATEMENT OF HON. DAVID K. GARMAN, ASSISTANT SECRETARY, ENERGY EFFICIENCY AND RENEWABLE ENERGY, DEPARTMENT OF ENERGY

Mr. GARMAN. Thank you, Mr. Chairman. I, too, will summarize my testimony.

As the chart behind me shows, there is an imbalance between domestic oil production and transportation's demand for petroleum. This imbalance, which is now around 11 million barrels a day, is projected to keep growing. And we're not going to close this imbalance with regulation, with new domestic production, or even both. Although promoting efficiency in the use of oil and finding new domestic sources of oil are important short-term undertakings, over the long-term, a petroleum-free option is eventually required. We ultimately want a transportation system that is free of dependence on foreign energy supplies and free of all harmful emissions.

We also want to preserve the freedom of consumers to purchase the kind of vehicles they want to drive, and that's the concept behind the Freedom CAR Partnership and the President's Hydrogen Fuel Initiative, which are designed to help develop the technologies necessary for hydrogen fuel cell vehicles and the infrastructure to support them.

A transportation system based on hydrogen provides several advantages. Hydrogen can be produced from diverse domestic sources, freeing us from a reliance on foreign imports. And when hydrogen is used to power a fuel cell, the combination results in more than twice the efficiency of today's gasoline engines and none of the harmful air emissions. In fact, the only byproducts of fuel cell operation are pure water and waste heat.

But to bring about the mass market penetration of hydrogen vehicles, government needs to partner with the private sector to conduct the research and development needed to advance investment in a hydrogen fuel infrastructure that performs as well as the petroleum-based infrastructure we already have, and that's going to be difficult.

Our gasoline infrastructure that we currently enjoy has been forged over the last century in a competitive market. It's remarkably efficient. It can deliver refined petroleum products that began as crude oil a half a world away to your neighborhood for less than the cost of milk, drinking water, or many other liquid products you can buy in the supermarket. We're currently bound to that petroleum infrastructure. And before drivers will purchase a fuel cell vehicle, they have to have confidence in a new hydrogen infrastructure. And that's why the President, in his State of the Union Address, made a new national commitment backed over the next 5 years by $1.2 billion for the Hydrogen Fuel Initiative, in addition to another $1/2 billion for associated vehicle technologies.

And government's not going to build this hydrogen infrastructure. The private sector will do that as the business case becomes clearer. But as we develop the technologies needed by the vehicles, we'll also develop the technologies required by the infrastructure. Some of the technology challenges are daunting. For example, we have to lower, by a factor of four, the cost of producing and delivering hydrogen. We have to develop more compact, lightweight, lower-cost hydrogen storage systems. We have to lower by a factor of at least 10 the cost of materials for fuel cells.

And, fortunately, we're not starting from scratch. Beginning back in November 2001, the Department of Energy began working with industry, academia, and other stakeholders on a comprehensive technology roadmap. We've achieved a remarkable level of consensus on what needs to be done.

And as important as hydrogen is for the long term, we've maintained a robust research and development program in non-hydrogen transportation technologies. Under the Freedom CAR Partnership, we've proposed a funding increase in fiscal year 2004 for our hybrid technology, as well as increases in materials technology. Many of these technologies will deliver fuel savings both prior to and after the introduction of fuel cell vehicles, since lightweight materials and hybrid technologies will most likely be incorporated into the fuel cell vehicle designs as well as the conventional and hybrid models that precede them.

Automakers are introducing technologies that have resulted in part from DOE's work in this area. At the recent Detroit auto show, the major U.S. automakers announced that they'll have a variety of new hybrid electric models entering the market in the 2004–2008 time frame. Of course, hybrid vehicles are more expensive compared to conventional vehicles, which is why the President proposed a tax credit for hybrid vehicles in his national energy plan and in subsequent budget submissions. And we urge Congress adopt these important incentives for more efficient vehicles.

So, with that, Mr. Chairman, I'd be pleased to answer any questions the Committee has, either now or in the future.

Thank you.

[The prepared statement of Mr. Garman follows:]

PREPARED STATEMENT OF HON. DAVID K. GARMAN, ASSISTANT SECRETARY, ENERGY EFFICIENCY AND RENEWABLE ENERGY, DEPARTMENT OF ENERGY

Mr. Chairman and Members of the Subcommittee, I appreciate this opportunity to testify today.

The President's National Energy Plan, entitled "Reliable, Affordable and Environmentally Sound Energy for America's Future," is the blueprint for the energy future we seek, and it makes several recommendations with regard to hydrogen.

Specifically, it directs the Secretary to develop next generation energy technology, including hydrogen; it recommends that our research and development (R&D) programs related to hydrogen and fuel cells be integrated; and it recommends that legislation reauthorizing the Hydrogen Energy Act enjoy the support of the Administration.

Since the release of the President's energy plan in May 2001, the President and Secretary Abraham have unveiled several exciting new initiatives related to hydrogen. Most notable are the FreedomCAR partnership announced in January 2002; the President's Hydrogen Fuel Initiative announced during the State of the Union address in January 2003; and the "FutureGEN" zero-emission coal-fired electricity and hydrogen power plant initiative announced in February. Each of these initiatives plays a particularly important role in a hydrogen energy future. Each will help make possible a future in which the principal "energy carriers" are hydrogen and electricity, eventually generated using technologies that do not emit any pollutants or carbon dioxide.

Today, we are highly dependent on coal, natural gas and nuclear energy for the majority of our electricity. We depend on oil, a growing percentage of which is imported, to power our transportation needs. In my testimony today I will focus on transportation, and the role that FreedomCAR could have in eventually building a light duty transportation system that requires no petroleum, and is comprised of vehicles that emit nothing other than water vapor. As illustrated in my first chart (Figure One) the "gap" between domestic production and transportation demand is growing—and is projected to keep growing. The current gap between total U.S. consumption and net production of oil is roughly 11 million barrels per day. Promoting efficiency in the use of oil, and finding new domestic sources of oil, are both important short-term undertakings. But over the long-term, a petroleum-free option is eventually required.

Our energy challenge is further complicated by another important factor—the pollutants and carbon dioxide emissions resulting from our use of energy. We have made tremendous progress in reducing pollutant emissions from our cars and trucks as well as our stationary power sources, and we will continue to make incremental gains through regulatory approaches such as the Tier II standards. But for true efficiency gains, we must reach to develop a wholly new approach to energy.

In his recent State of the Union address, President Bush announced a groundbreaking plan to transform our Nation's energy future from one dependent on foreign petroleum, to one that utilizes the most abundant element in the universe—hydrogen.

Hydrogen can be produced from diverse domestic sources, freeing us from a reliance on foreign imports for the energy we use at home. Hydrogen can fuel ultra-clean internal combustion engines, which would reduce auto emissions by more than 99 percent. And when hydrogen is used to power fuel cell vehicles, it will do so with more than twice the efficiency of today's gasoline engines—and with none of the harmful air emissions. In fact, fuel cells' only byproducts are pure water and some waste heat.

But ultimate success in the mass-market penetration of hydrogen fuel cell vehicles requires a hydrogen-based infrastructure that performs as well as the petroleum-based infrastructure we now have.

Our current gasoline/hydrocarbon infrastructure has been forged in a competitive market. It is ubiquitous and remarkably efficient. It can deliver refined petroleum products that began as crude oil half a world away to your neighborhood for less than the cost of milk, drinking water, or many other liquid products you can buy at the supermarket. We are currently bound to that infrastructure. We have no alternative. Eventually replacing it with something different will be extremely difficult. But that is what we must do if we expect to achieve success with the FreedomCAR partnership. Drivers must be able to go anywhere in America and to refuel their hydrogen-powered vehicle before they will be comfortable purchasing one.

That is why the President, in his State of the Union address, proposed that we in the federal government significantly increase our spending on hydrogen infrastructure R&D, including hydrogen production, storage, and delivery technologies, as well as fuel cells. Over the next five years, we plan to spend an estimated $1.7 billion on the FreedomCAR partnership and Hydrogen Fuel Initiative, $1.2 billion of which is for the Hydrogen Fuel Initiative, which includes resources for work on hydrogen and fuel cells. Of the $1.2 billion figure, $720 million is "new money."

We will not build the infrastructure. The private sector will do that as the business case becomes clear. But as we develop the technologies needed by the vehicles, we will also develop the technologies required by the infrastructure. In cooperation with DOT, we will convene the parties needed for technology partnerships, we will collaborate on the needed codes and standards, and we will promote international cooperation in this effort. Just last week, during a presentation to the International Energy Agency, Secretary Abraham called for an "International Partnership for the Hydrogen Economy" to collaborate on research and deployment of hydrogen technologies.

I will now elaborate further on some of these technology challenges we face and the timing of the transition toward a hydrogen economy.

Technology Challenges

Achieving our vision will require a combination of technological breakthroughs, market acceptance, and large investments in a national hydrogen energy infrastructure. Success will not happen overnight, or even over years, but rather over decades; it will require an evolutionary process that phases hydrogen in as the technologies and their markets are ready. Success will also require that the technologies to utilize hydrogen fuel and the availability of hydrogen occur simultaneously.

Some of the significant hurdles to be cleared include:

- Lower by a factor of four the cost of producing and delivering hydrogen;
- Develop more compact, light weight, lower cost, safe, and efficient hydrogen storage systems that will enable a greater than 300 mile vehicle range;
- Lower by a factor of ten the cost of materials for advanced conversion technologies, especially fuel cells;
- More effective and lower cost (by a factor of at least ten) carbon-capture and sequestration processes (a separate program critical to fossil-based production of hydrogen);
- Designs and materials that maximize the safety of hydrogen use; and,
- Finally, we must solve the overarching infrastructure challenges to develop a hydrogen-based delivery and refueling infrastructure comparable to the petroleum-based one we have today. The development of needed codes and standards as well as the education of consumers relative to the use of hydrogen can help safely establish this hydrogen infrastructure.

The Department has drafted a work breakdown structure associated with each of the critical areas (production, delivery, storage, conversion, and end-use) identified in the National Hydrogen Energy Roadmap unveiled by the Secretary last November. We have developed critical milestones and decision points that will help us gauge technology progress. Examples of key program milestones that support FreedomCAR and achievement of a hydrogen economy include the following:

- On-board hydrogen storage systems with a six percent capacity by weight by 2010; more aggressive goals are being established for 2015;
- Hydrogen production at an untaxed price equivalent to $1.50 per gallon of gasoline at the pump by 2010;
- Polymer electrolyte-membrane automotive fuel cells that cost $45 per kilowatt by 2010 and $30 per kilowatt by 2015 and meet 100,000 miles of service life; and,
- Zero emission coal plants that produce hydrogen and power, with carbon capture and sequestration, at $0.79 per kilogram at the plant gate.

In the near future, we plan on partnering with energy companies to establish more specific goals related to technology and components needed to produce and distribute hydrogen using various fossil, nuclear and renewable pathways. In this exercise, we will be looking at the full range of hydrogen technology areas covered in the Roadmap.

Advances in other technologies will also be necessary for the ability of a hydrogen-fueled vehicle to realize its full potential. These include:

- Improved energy storage, (e.g., batteries that are more durable, cheaper, and better performing);
- More efficient and cost effective electric motors;
- Inexpensive and more effective power electronics; and,
- Better materials for lighter, but strong, structural members.

These technologies will enable hydrogen-fueled vehicles to be more efficient, and to help lower the vehicle cost to the consumer.

In the near- to mid-term, most hydrogen will likely be produced by technologies that do not require a complete hydrogen distribution infrastructure (i.e., using existing distributed natural gas infrastructure). As RD&D progresses along renewable, nuclear, and clean coal and natural gas production pathways (including techniques for carbon sequestration) a suite of technologies will become available in the mid- and long-term to produce hydrogen from a diverse array of domestic resources. The economic viability of these different production pathways will be strongly affected by regional factors, such as feedstock availability and cost, delivery approaches, and regulatory environment.

Detailed analysis of life-cycle costs and benefits for alternative hydrogen production pathways, carbon sequestration, and other elements will continue. "Well-to-Wheels" analyses conclude that the energy and environmental benefits depend greatly on how hydrogen is manufactured, delivered and stored, and on the economic feasibility of sequestration for fossil feed stocks. The results of these studies will help in making down-select decisions and to ensure that the relative merits of specific hydrogen pathways are evaluated properly and in comparison with other energy alternatives. In fact, we are now following up on a National Academy of Sciences recommendation to establish a more robust systems analyses effort so that we can optimally prioritize areas for R&D, as well as understand the ramifications of future R&D successes and disappointments. Out-year planning will identify needs for RD&D on production and storage technologies, delivery infrastructure, and education and safety/codes and standards. Public education of consumers and local code officials must also be pursued concurrently with the RD&D.

Finally, industry must develop and construct the infrastructure to deliver hydrogen where it is needed. We will work with the DOT to help industry develop a safe, efficient, nation-wide hydrogen infrastructure. The hydrogen distribution infrastructure can evolve along with the conversion and production technologies, since much of the infrastructure that is developed for fossil-based hydrogen will also be applicable to renewable- and nuclear-based hydrogen. We will partner with industry to develop infrastructure in pilot projects, and industry will expand locally, regionally, and ultimately nationally.

Interim Strategies

As important as we believe hydrogen is for the long term, we are still working, in cooperation with other federal agencies, to maintain a robust, and in some areas growing, research and development program in non-hydrogen transportation technologies.

Under the FreedomCAR partnership we have proposed a funding increase in fiscal year 2004 for our hybrid technology, as well as increases in materials technology. We believe many of these technologies will deliver fuel savings both prior to and after the introduction of fuel cell vehicles, since lightweight materials and hybrid technologies are expected to be incorporated into fuel cell vehicle designs. Therefore, these investments are expected to pay off in the interim, as well as over the long term.

In addition, we had a number of interim strategies in mind as we established specific, measurable performance goals for our program. And our FY 2004 budget is aligned with these goals. For example:

- We are working to develop technologies for heavy vehicles by 2006 that will enable reduction of parasitic energy losses, including losses from aerodynamic drag, from 39 percent of total engine output in 1998 to 24 percent;
- The 2006 goal for Transportation Materials Technologies R&D activities is to reduce the production cost of carbon fiber from $12 per pound in 1998, to $3 per pound; and,
- The 2010 goal for Hybrid and Electric Propulsion R&D activities is to reduce the production cost of a high power 25kW battery for use in light vehicles from $3,000 in 1998 to $500, with an intermediate goal of $750 in 2006, enabling more cost competitive market penetration of hybrid vehicles.

Automakers are introducing technologies that have resulted in part from DOE's work in this area. At the recent North American International Auto Show in Detroit, the major U.S. automakers announced that they will have a variety of new hybrid gasoline-electric models entering the market in the 2004–2008 timeframe.

Of course, hybrid vehicles are more expensive compared to conventional vehicles, which is why the President proposed a tax credit for hybrid vehicles in his National Energy Plan, and subsequent to that in his 2004 budget submission. We urge that Congress adopt this important incentive for more efficient vehicles.

And we will continue support for our Clean Cities program, a unique, voluntary approach supporting more than eighty local coalitions that deploy alternative fuel vehicles (AFVs) and promote supporting infrastructure.

The Administration strongly supports a renewable fuels standard (RFS) that will increase the use of clean, domestically produced renewable fuels, especially ethanol, which will improve the Nation's energy security, farm economy, and environment.

As important as the RFS and the Clean Cities program are, their goals illustrate the daunting challenges we face. Taken together, the RFS and Clean Cities are expected to offset about four billion gallons of petroleum use per year by 2010. That sounds impressive until it is compared to the demand for petroleum for transportation uses. In the year 2000, we used approximately 130 billion gallons of gasoline and over 33 billion gallons of diesel (highway use only). With that realization, the critical importance of the FreedomCAR partnership and Hydrogen Fuel Initiative as a long-term strategy becomes clear.

And, if we are to achieve real progress in the near term and our ultimate vision in the long term, we must continue to nurture productive partnerships with the private sector. It is the private sector that will make the major investments necessary for the transition to a radically different transportation future. Those investments will not be made in the absence of a clear-cut business case.

Transition to a Hydrogen Economy

We consider the transition to the hydrogen economy as occurring in four phases, each of which requires and builds on the success of its predecessor, as depicted in Chart 2. The transition to a hydrogen-based energy system is expected to take several decades, and to require strong public and private partnership. In Phase 1, government and private organizations will research, develop, and demonstrate "critical path" technologies and safety assurance prior to investing heavily in infrastructure. This Phase is now underway and will enable industry to make a decision on commercialization in 2015.

The FY04 Budget currently before Congress is consistent with completion of the technology RD&D phase by 2015.

Phase II, Transition to the Marketplace, could begin as early as 2010 for applications such as portable power and some stationary applications, and as hydrogen-related technologies meet or exceed customer requirements. If an industry decision to commercialize hydrogen fuel cell vehicles is made in 2015, mass-market penetration can begin to occur around 2020. Consumers need compelling reasons to purchase new products; public benefits such as high fuel use efficiency and low emissions are not enough to overcome the market advantages of the incumbent technology and infrastructure. The all-electronic car powered by hydrogen fuel cells is one example of an approach to greater value delivery; it could offer the consumer greater amenities, improved performance through elimination of mechanical parts and greater design flexibility.

As these markets become established, government can foster their further growth by playing the role of "early adopter," and by creating policies that stimulate the market. As markets are established this leads to Phase III, Expansion of Markets and Infrastructure. The start of Phase III is consistent with a positive commercial decision for vehicles in 2015. A positive decision will attract investment in infrastructure for fuel cell manufacturing, and for hydrogen production and delivery. Government policies still may be required to nurture this infrastructure expansion phase.

Phase IV, which should begin about 2025, is Realization of the Hydrogen Vision, when consumer requirements will be met or exceeded; national benefits in terms of energy security and improved environmental quality are being achieved; and industry can receive adequate return on investment and compete globally. Phase IV provides the transition to a full hydrogen economy by 2040.

Conclusion

Mr. Chairman, it will take a great deal to achieve this vision of a hydrogen energy future we are all talking about this afternoon. It will require careful planning and coordination, public education, technology development, and substantial public and private investments. It will require a broad political consensus and a bipartisan approach. Most of all, it will take leadership and resolve.

The President has demonstrated his leadership and resolve. “With a new national commitment,” said the President during his State of the Union address, “our scientists and engineers will overcome obstacles to taking these cars from laboratory to showroom, so that the first car driven by a child born today could be powered by hydrogen and pollution free.”

A few days later at an event on energy independence featuring new uses for fuel cells including automobiles, the President reiterated his commitment to his new Hydrogen Fuel Initiative stating, “The technology we have just seen is going to be seen on the roads of America. And it’s important for our country to understand that by being bold and innovative, we can change the way we do business here in America; we can change our dependence upon foreign sources of energy; we can help with the quality of the air; and we can make a fundamental difference for the future of our children.”

We believe that the benefits the President envisions are attainable within our lifetimes and will accrue to posterity, but they will require sustained work and investment of public and private financial resources. We at the Department of Energy welcome the challenge and opportunity to play a vital role in this Nation’s energy future and to support our national security in such a fundamental way.

This completes my prepared statement. I would be happy to answer any questions you may have, either now or in the future.

Figure 1: Oil Use in Transportation Plotted against Domestic Production

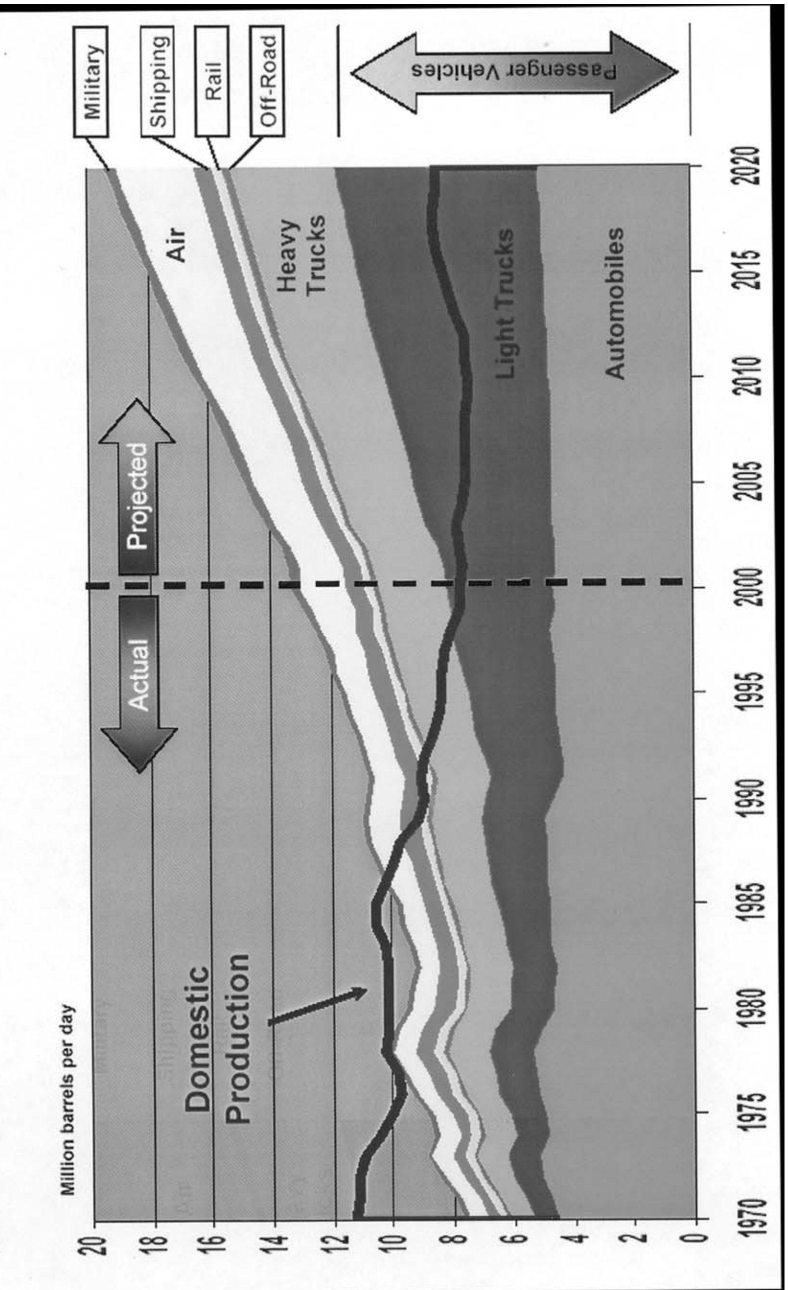
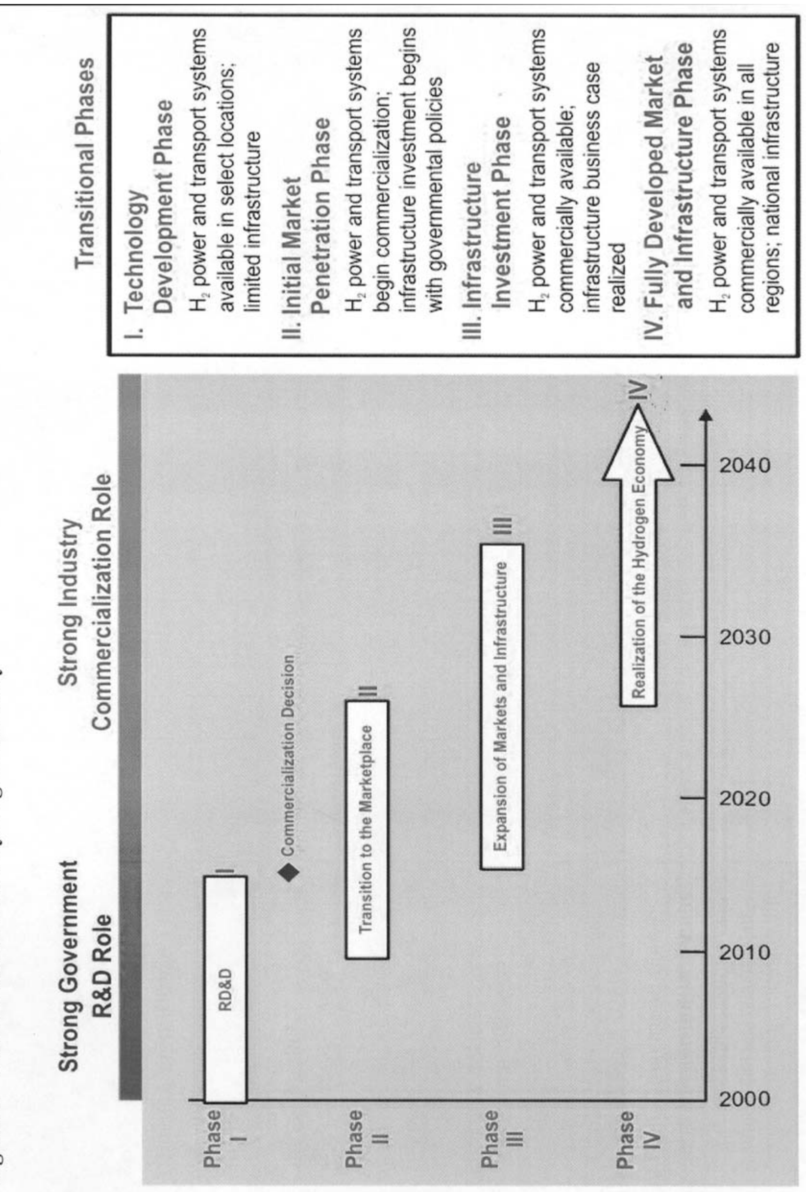


Figure 2: The Transition to the Hydrogen Economy



Senator BROWNBACK. Thank you very much, Mr. Garman.

There's a number of questions that I have. And let's run the clock here about 7 minutes, if we could, for questions back and forth. Both of you put forward the promise of this for the future, and we can see the beauty of that. Both of you put forward a series of technical and cost hurdles to overcome in both the fuel and in the vehicle. Is this doable, to be able to meet these costs and technical hurdles? And in what time frame are we talking about being able to do that, if it is achievable?

Mr. MARBURGER. Dave, you're closer to the technical details. I'll do the high-level content-free questions, and you can do the technical questions.

Mr. GARMAN. The President's words in the State of the Union were really chosen very carefully when he said a child born today should be able to purchase a hydrogen fuel cell vehicle when he's ready to drive. We think that the components can be in place for commercialization on the merits of the business case for the automakers to make a decision to proceed with mass-market introduction of the vehicles. That decision can happen around 2015, with real mass-market introduction by 2020. Some of the automakers are saying perhaps that can come sooner if the refueling infrastructure is in place.

Our general findings with respect to alternative fuel infrastructure is that fueling stations, about 20 percent in urban markets and 50 percent in rural markets need to have the alternative fuel available or customers won't have confidence in purchasing the vehicles. So we have to attack this chicken-and-the-egg problem, not only the vehicles, but also the infrastructure, and that is going to take some time. So I think 2015/2020 is the correct time frame.

Mr. MARBURGER. Let me add to that by pointing out that there are current applications of stationary fuel cells for backup power, and they are developing a market. They're developing the industry and, together with that, the infrastructure that will be necessary as the applications move on into the transportation sector.

Senator BROWNBACK. Mr. Garman, what do you base that projection of 2015—you're 12 years out from that—that you could get to a commercialization phase, and you're talking about a factor of 4 on the price of the fuel, a factor of 10 on the actual fuel cell vehicle itself—where do you see those great advances coming in such, really, a pretty short period of time?

Mr. GARMAN. We're heartened, in part, by some great advances that have happened in the recent past. For example, the cost of fuel cells themselves have been brought down by an order of magnitude in the last 5 or 6 years as a consequence of some of the work done at the national labs and in the private sector on reducing the amount of platinum and other precious metals needed for the fuel cell membrane. We have, through this road-mapping process that I referred to and bringing all of the parties together to understand what the technology hurdles were, have really developed a pretty tight set of R&D goals, beginning in the 2010 time frame.

If we are successful in meeting all of our 2010 goals—and I'll provide them for the Committee; it's sort of engineering-type-based goals—but if we're successful, we believe we'll have the basic technology components necessary for the vehicle in place—the technology, the capability, at least—somewhere after the 2010 time frame. So we've given a great deal of thought to these possibilities.

You know, the price of, for instance, hydrogen from natural gas, yes, today it is four times higher than it needs to be, but we are already opening some demonstration stations, hydrogen refueling stations, and learning a great deal about how to improve the efficiency of the hydrogen production, how to optimize compression, storage, and some of the other elements that need to be in place to make sure we can meet our cost targets.

And the reason we are doing these cost targets kind of consistent with the President's management agenda and linking the budget that we're asking Congress for with the achievement of performance goals that we've articulated, we hope to be transparent to the Congress so that you will know and we will know how we're progressing against those goals going ahead.

Senator BROWNBACK. Mr. Garman or Mr. Marburger, either one of you. Senator Dorgan and I have one similar feature that we have between our States—there are a number of them, but we do have plenty of wind energy. And we've had windmills and wind electricity generation be recently constructed. Of course, it's been a power source since people have been farming in it, but the big problem is the sporadic nature of wind energy and then being able to put that into the grid in a timely or usable fashion. But if you did convert that wind energy into hydrogen and store and receive it, it does seem to answer significant questions for wind energy and possibly for hydrogen. Is that correct, or is that too simplistic of a view of putting together these resources?

Mr. GARMAN. No, that's absolutely correct. We have to—because we're using electrolysis as the mode of hydrogen production there, which is the conversion of one energy carrier to another. And there's a certain loss of efficiency whenever you do that. We want to make sure that the underlying wind technology, we continue to bring down the cost of generating electricity from wind. That's very important.

And also, we're going to have to do a little bit of work on how we get the hydrogen from its point of production, at the wind turbine or close to it, to where it needs to go. We do have, today, hydrogen pipelines, about 700 miles worth in this country. We operate them at pretty low pressures. If we were to want to operate large hydrogen pipelines at much higher pressures, we're going to have some materials issues and some other things that we have to confront. We think we can do this. We don't see any showstoppers. The issue is, as always, cost—competing with that tremendously low cost that energy companies are able to deliver gasoline to your neighborhood for. That's what we have to compete with, and that's a tough competitor.

Senator BROWNBACK. Mr. Marburger?

Mr. MARBURGER. Yes, I'd like to add to that, in that hydrogen is not only a great way to store energy, it's a great way to deliver it. Because unlike electricity, which has to be brought from the production source to the user by a wire which loses a lot on the way, hydrogen doesn't lose any of its electricity en route. So if you can have pipeline distribution, it could be much more efficient than electrical energy distribution over wires. And this is potentially another attractive feature.

Senator BROWNBACK. As you mention, though, Mr. Garman, that we've got to get more efficient production of electricity, then in the present scenario are we likely to produce hydrogen via coal because of the expense, and are we having another set of environmental issues, then, that are forward with producing hydrogen via coal?

Mr. GARMAN. We wouldn't want to do that unless we were successful at sequestration technology. And, of course, there are—you know, if I wanted to produce hydrogen from coal, what I would do is gasify the coal, split off the hydrogen from that gas created, and then take the carbon dioxide, the sulfur, and the other elements in that gas and sequester that in, say, deep unminable coal seams or saline aquifers so that that's not released to the environment. That is a way, theoretically, that we could cleanly use coal.

In the near term, we believe that most of the hydrogen will be produced from natural gas, the way hydrogen is produced today. We produce some 9 million metric tons of hydrogen each and every year using natural gas. We would need 40 million metric tons to drive a fleet of 100 million vehicles. So we're really not that far apart, in terms of what we produce today and what we would need to drive a fleet of vehicles.

So in the near term, we think natural gas would probably be the feed stock. But, again, the great thing about hydrogen is that we can, on the farm, gasify agricultural residues that are currently left in the field. That can be turned into hydrogen. There's just a variety of methods and processes that we can use. One day we hope to be able to use microbes, bacteria, algae, some other things that, even through genetic modification or other means, we can use to actually create hydrogen, or to synthesize hydrogen, if you will. So this gives us lots of options as a nation.

Senator BROWNBACK. Senator Lautenberg?

Senator LAUTENBERG. Yes, thank you, Mr. Chairman.

Mr. Garman, accompanying your statement is a graph that says the oil used in transportation plotted against domestic production. And that's a grim prospect, obviously. When we got to the 2000 line, the difference between available oil from domestic sources and that which is presently used began to widen substantially. And so here we are with an expectation that we're going to have to use far more than twice that which we are able to produce domestically, and we're looking at a program that has a lot of potential, but also a lot of practical problems associated with it. Namely, cost, as I looked at Mr. Marburger's statement.

So if those are the projections, why wouldn't we be wise to step up the funding that is offered from the Government, considering that the automobile manufacturers are spending between $2- and $3 billion each year on hydrogen fuel vehicle research, and we're proposing $1.2 billion. We're going to be throwing away a lot of money long-term in this process, and wouldn't you think that the situation is more emergent than $1.2 billion and that we ought to try to see what we can do about expanding that, match the private sector, and really show that the commitment's a serious one?

Because I think that if people look at a $1.2 billion spent here, that energy is probably the second or third highest priority, in terms of our need as a society. I mean, we're drowning in pollution, and the dependency on others for our product, our needs, and I think that we have to declare an emergency alarm and get on with the investment.

I take it, from each of you, that the practicality is there. But the question of how you get this into production is a fairly good-sized task. But money can cure a large part of that. We're going to be spending the money. It's a question of where we spend it and when we spend it.

Mr. GARMAN. I would respond and agree that there's both a short-term challenge and a long-term challenge and would argue that the most appropriate use of Federal R&D dollars is in long-term technology.

Automakers have technology to produce high-mileage cars today. You can buy high-mileage cars today. I drive a car that gets over 50 miles per gallon. It's available. The problem is the consumers, for one reason or another, are not choosing to purchase high-mileage cars, because it doesn't give them the features that they want in a vehicle.

And what's, sort of, different and remarkable about fuel cell vehicles is that a fuel cell vehicle, like the one you saw, the General Motors car, outside today and others being planned by the other automakers, actually provide advantages that consumers will want to buy. It actually gives them advantages, it does things that their vehicles today can't do. And it also confers certain public benefits, like reducing our dependence on foreign oil and making our air cleaner to breathe.

So I think that our approach is a good one to make the investments in the long term R&D. We have other tools at our disposal, and, in fact, the administration used corporate average fuel economy standards. When you look at that graph, you see that the largest increase in petroleum use is in the light truck category. And just a couple of weeks ago, the administration increased CAFE standards on light trucks for the first time since the 1996 model year, and it was the largest increase in standards in 20 years, I believe. So there are various mechanisms that are available to us.

I think the right role for R&D is to solve these truly difficult technical challenges that we have to this alternative that will make these debates about corporate average fuel economy standards absolutely moot, totally remove the automobile from the environmental equation, and totally remove the geopolitics of oil from our transportation problems.

Senator LAUTENBERG. Well, do you think, therefore, then, the pace is an acceptable one at this juncture? Can we accelerate the pace of development by spending more money, or are the automobile companies being foolish in the amount that they're investing?

Mr. GARMAN. We're guided, in part, by the roadmap work that we developed in partnership with private sector, nongovernmental organizations, and others. The truth is, yes, more money can accelerate some things, but you also need time. You need learning cycles where you actually put the technology on the road, discover where the improvements need to be made, redirect your R&D to solve the problems, and then, again, go through another learning cycle to put the next-generation technology on the road.

So, yes, money is useful, and we're glad the President has entrusted us with these resources, but we also need some time.

Senator LAUTENBERG. I think we also need some encouragement, when you say that the consumers haven't turned to these things with a rush certainly. But I've never heard a word—and, by the way, it's not unique to this administration, but over the last years—I haven't heard the word "conserve," "sacrifice," "do your part," "help us reduce our dependence," and "if you need a second vehicle, look at the gasoline, the mileage consumption there per gallon"—and encourage the industry rather than I think what we're doing. There is a delicate balance between jobs and investment and—but the industry, generally, has been permitted to set its own timetable. There were several times in my previous term here when we tried to raise the CAFE standard, and it just couldn't go anywhere.

I think in view of what is an emergency character to where we're going, I would think that a more aggressive campaign coming out of the administration talking about, you know, "You want to do your part. If you need another something, then look at the mileage standards and see what that looks like." And, really, because we know that the vehicles—there are vehicles available that get more mileage. I looked at that car, and I'm trying to figure out what it is that you saw in that car that you can't get in other cars. But perhaps we can talk about that privately.

I thank you, Mr. Chairman.

Senator BROWNBACK. Thank you very much.

If I could ask one follow-up of Secretary Garman. Based on your experience and your knowledge, what are the greatest challenges—and I'd like for you to put these in priority order—to the deployment of hydrogen fuel cell cars? What are the specific set of questions that we have to answer in list of importance as you look at this issue?

Mr. GARMAN. Number one, I would say, is storage. Storage of hydrogen onboard the vehicle. Consumers are only going to buy a vehicle that gives them a range of 300 or 350 miles between refuelings. And the nature, the physical nature, of hydrogen is such that it's difficult to store in a manner that—without using a lot of weight and bulk. And weight and bulk is, in essence, the enemy of an automaker trying to design a car that consumers will want to buy.

So, you know, the method of storing hydrogen today is by compressing it in a 5,000- or 10,000-pounds-per-square-inch vessel, pressure vessel. We're looking at a variety of technologies, like chemical hydrides, metal hydrides, carbon nanotubes, other types of materials that can store hydrogen at close to ambient temperatures and pressures. That, I would say, is number one.

Number two, I would say, is probably the cost of the hydrogen itself. It needs to be competitive with the cost of gasoline if we're going to get in the ballpark. Maybe down the road, Congress can deal with some policy incentives, in terms of how hydrogen is taxed or other things, but we've got to make sure that we can produce hydrogen close to the cost of its competitor before consumers will feel comfortable purchasing the car.

And, third, you might think about making hydrogen out of ethanol. Biomass is a tremendous opportunity for hydrogen.

Senator BROWNBACK. Good.

Mr. GARMAN. Absolutely.

Senator BROWNBACK. Nice statement.

[Laughter.]

Mr. GARMAN. And, third, the cost and durability of the fuel call itself. They're about an order of magnitude too high today. And also the durability of the fuel cell of—you know, when you buy a car, you want to make sure it's going to go 120,000 or 150,000 miles, and that's going to require about a 5,000-hour life on the fuel cell. Today, the fuel cells are lasting, you know, 1,000 hours or 2,000 hours. We need to improve the durability and lower the cost of the fuel cell.

Those items, I would think, are the big three.

Senator BROWNBACK. And you don't see any of them as insurmountable within this 12-year time frame that you're talking about?

Mr. GARMAN. I probably worry a little bit more about storage than the others. And, we've pulled together Nobel Laureates and other prize-winning scientists to help us tackle this problem.

Senator BROWNBACK. And they feel it is accomplishable?

Mr. GARMAN. Yes. I mean, we're going to need a technology breakthrough on that one. All the others, I think we can do without a major technology breakthrough, but on the storage, I think we're going to need a technology breakthrough.

Senator BROWNBACK. Like what? What sort of technology breakthrough are you——

Mr. GARMAN. A composition of a metal hydride, for instance, we've got metal hydrides that come close, just not quite there yet—that can actually hold the hydrogen molecules in its matrix without having to use high pressure for storage. And this is kind of a materials challenge, and this is—I yield to the expert, who's an actual scientist. He doesn't just play one on TV.

Mr. MARBURGER. Let me just comment on the relevance of other national priorities for basic research to this problem. These new materials are designed and improved through the processes of nanotechnology. The National Nanotechnology Initiative is likely to produce new materials and new materials preparation processes that will be very relevant, both to the storage and to the fuel cell membranes and electrodes, themselves, and that the figures of merit on these materials have been improving gradually.

But I agree with Dave, a technology breakthrough will be necessary. But in view of the many opportunities that exist—for example, Dave mentioned carbon nanotubes; if we can find a way to manufacture carbon nanotubes in much larger quantities——

Senator BROWNBACK. Slow me up here a little bit. Carbon nanotubes. I realize I chair this Subcommittee, but I don't—what are you talking about?

[Laughter.]

Mr. MARBURGER. These are nanoscale structures made out of carbon atoms that have unusual geometrical properties, and they have strength properties and electrical-conductivity properties, but they also have properties that may make them suitable for storing hydrogen. And the problem with them now is that they're difficult to manufacture in the quantities and specifications that you need.

So lots of people are working on this, because there are other applications of carbon nanotubes, as well. And we hope for a crossover kind of result that can stimulate developments in the fuel cell business, the hydrogen business.

Senator BROWNBACK. You know, we've doubled funding at NIH over a 5-year time period, widely supported amongst the Congress, a strong feeling that we were just very close to some major breakthroughs in health research and medical information technology, drugs, treatment. Would we have the same sort of promises if we did something similar with NSF, National Science Foundation, as some people have kicked that idea around? Are we on some of the breakthroughs that we need in this and a number of other areas if we significantly increase that investment?

Mr. MARBURGER. NSF is currently the largest shareholder in the National Nanotechnology Initiative, and there are certainly very, very important benefits to come from funding those initiatives, that initiative in the Department of Energy and other big physical science agencies, as well. Our preference is to focus on the priorities and on the areas of science that are likely to create breakthroughs like this. The physical sciences have been identified as an area that's in need of additional support. And in the President's fiscal year 2004 budget request, a number of physical sciences programs and projects are singled out for increased funding, including five new nanotechnology materials centers in Department of Energy laboratories, all of which, I can assure you, will be recruited for basic research on a hydrogen economy.

Senator BROWNBACK. Sounds like a topic we'll need to cover at a future hearing.

Gentlemen, thank you very much. I would like the one document you talked about, Mr. Garman, to be submitted into the record, that would be appreciated. *

Senator BROWNBACK. Very good testimony.

Call for the second panel. The second panel is Dr. David Friedman. He's the senior engineer of Clean Vehicles Program for the Union of Concerned Scientists. Mr. Byron McCormick, the Executive Director of fuel cell activities for General Motors Corporation. And Mr. Francis Preli, Jr., vice president of engineering, United Technologies Corporate Fuel Cells.

Gentlemen, we're delighted to have you here this afternoon. Your written statements will be put into the record as presented, so you're free to summarize if you would choose to do so.

Dr. Friedman, we will start with you. And the microphones, pull them up close, if you will. They're not the best technology.

STATEMENT OF DAVID J. FRIEDMAN, SENIOR ENGINEER, CLEAN VEHICLES PROGRAM, UNION OF CONCERNED SCIENTISTS

Dr. FRIEDMAN. Thank you, Mr. Chairman, and thank you for the opportunity to testify before you today.

My name is David Friedman, and I'm a senior engineer with the Union of Concerned Scientists. UCS is a nonprofit organization of more than 60,000 scientists and citizens working for practical environmental solutions.

Now, as I start, I just want to note that in the 5 minutes it will take me to speak today, we will spend over $1 million overseas to buy oil. That is $200,000 that leaves the U.S. economy every

* The document is included in Mr. Garman's prepared statement.

minute. This economic burden will continue to grow as long as the U.S. is tied to oil. We will be susceptible to OPEC's market power and Persian Gulf instability. We will also be contributing to many significant environment problems that impact our health and our economy.

While there is no single silver bullet to address this problem, there is a set of technologies that offer short-, medium-, and long-term solutions to our transportation oil problem. Given the size of this problem, we must put each of these tools to work. Today I would like to talk about these technologies and where hydrogen fuel cells fit in.

If you would turn your attention to this chart, the top edge, very similar to the chart that Secretary Garman showed, shows the projected oil use for U.S. cars and trucks only, today starting at about 8 million barrels per day and reaching over 14 million barrels per day by 2020. In the short term, as seen in the blue-shaded area, cost-effective conventional technologies are available and can be put on the road to quickly and dramatically slow the growth of oil use from cars and trucks while also saving consumers money. These technologies include efficient gasoline engines, like General Motors' displacement-on-demand technology. They also include more efficient transmissions, improved aerodynamics, high-strength steel, and lower rolling-resistance tires. Diesel is another conventional technology option, but it will not be as cost effective as other existing technologies, and it will make it harder to address air quality concerns.

Because these conventional technologies exist and are cost effective, we do not need a major research program to get them on the road. Instead, we need automakers to put them in the showrooms, providing consumers with choices they currently do not have, things like a 35-mile-per-gallon Ford Explorer or a 33-mile-per-gallon Chevy Silverado pickup.

The administration recently set an extremely modest 4-year goal for increasing light truck fuel economy standards by 1.5 miles per gallon. This will have a negligible impact on our oil use, barely affecting the top line. It will save less than one day's worth of oil each year between 2005 and 2008. Significantly more can be done with the use of conventional technologies, as the blue-shaded area in this chart shows.

In the medium term, as shown in the red-shaded area, hybrid technology can stabilize our passenger-vehicle oil use through 2020 building on the gains made by near-term conventional technology. Our analysis indicates that hybrid technology can lead to a fleet of 55- to 65-mile-per-gallon cars and 40- to 50-mile-per-gallon trucks in the 2015 to 2020 time frame.

Dedicated alternative fuel vehicles also offer near- and medium-term air quality and oil savings benefits. And fuels such as natural gas and possibly methanol will provide a major source of hydrogen in the transition to renewable hydrogen feed stocks.

These technologies also do not require major public funding for research, but they will be more expensive than other options, especially in the near-term. For this reason, temporary performance-based market incentives will be important to get a sufficient number of vehicles and fuel on the road to bring down their costs.

Finally, hydrogen fuel cell vehicles, as shown in the green-shaded area, build on gains from conventional and hybrid technology, and together they can dramatically reduce projected oil use. By 2030 and beyond, hydrogen fuel cell vehicles can put us on a path to effectively eliminate our passenger vehicle oil use. But, again, that's 20 to 30 years away, and there are many technologies that can do a lot in the interim.

There is a need for government-funded research and demonstration on fuel cells and fuel cell vehicles to ensure that clean hydrogen fuel and vehicles can be made available. Temporary performance-based market incentives for fuel cell vehicles, hydrogen, and, importantly, renewable energy resources will also be important to bring down costs.

These research programs and incentives must also recognize that hydrogen is not inherently clean. Instead, it is an energy carrier that is only as clean as the source. Accelerating the movement to a clean hydrogen future will not be a small or inexpensive task, but the benefits far outweigh the costs. To be successful, such a program will need a clear timetable, along with concrete vehicle production and supply goals, and that's something that is missing from the administration's current plans.

In closing, I just want to say that as an engineer, I see this broad array of technology that is available as an opportunity. It's an opportunity to roll up our sleeves and get to work making vehicles that are safer, cleaner, and less dependent on oil.

Because the available conventional and advanced technologies complement each other, this is not an either/or proposition. We don't have to choose between conventional improvements, hybrids, and fuel cell vehicles. We can do them all and dramatically reduce our oil dependence. We must continue to focus on policies that will put conventional technology to work while we also invest in these longer-term options.

Thank you for the opportunity to testify today.

[The prepared statement of Dr. Friedman follows:]

PREPARED STATEMENT OF DAVID J. FRIEDMAN, SENIOR ENGINEER, CLEAN VEHICLES PROGRAM, UNION OF CONCERNED SCIENTISTS

Thank you Mr. Chairman and Members of the Committee for the opportunity to testify before you today. My name is David Friedman and I am a Senior Engineer in the Clean Vehicles Program at the Union of Concerned Scientists (UCS). UCS is a nonprofit organization of more than 60,000 scientists and citizens working for practical environmental solutions.

Today, I would like to begin by briefly describing the numerous challenges—ranging from growing dependence on foreign oil to public health concerns—posed by our transportation sector. I will then focus on both the technologies available today as well as the technologies of the future that will help us meet these challenges. UCS firmly believes that technology is available today that can increase our efficiency, help protect public health and provide consumers with safe transportation. There is no single silver bullet, but there is a set of technology that offer short, medium and long-term solutions to our transportation oil problem. Given the size of this problem, we must put each of these tools to work. We must continue to focus on policies that will put that technology to work for us now even while we invest in the technologies of the future.

Energy, Oil, and the Transportation Sector

The United States currently uses about 20 million barrels of oil each day. Two thirds of that oil is used in the transportation sector. So, the economic, political, environmental and health risks associated with our oil dependence are inherently linked to the amount of fuel our transportation system requires every day.

Oil Markets

As the world's largest oil consumer, the United States is particularly exposed to the risks posed by an oil market beyond our control. Reliance on the economically powerful OPEC cartel [1] and the politically unstable Persian Gulf nations will only grow over time as oil supplies dwindle. OPEC owns four-fifths of the world's remaining proven oil reserves and nations in the Persian Gulf own two-thirds (Figure 1). Only a small proportion—about 2 percent—of the proven reserves lies within the United States.

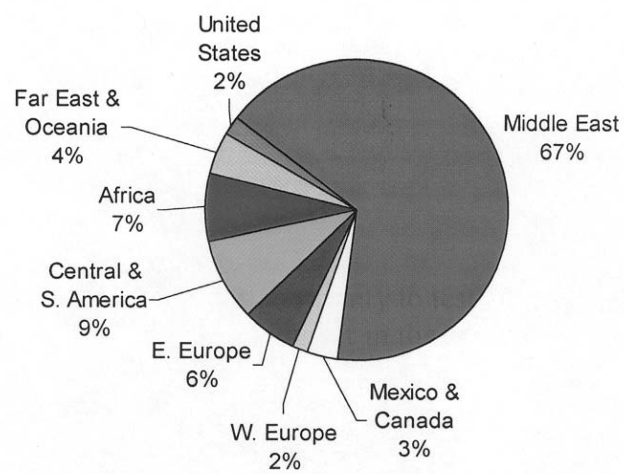


Figure 1. World Oil Reserves by Region, 2000

Economic Impacts

Importing large amounts of oil carries significant economic costs: we send more than $200,000 overseas each minute to buy foreign oil. [2] But even if we imported no oil at all, the U.S. economy would still be vulnerable. The world oil market determines the price we pay for oil, so global price hikes affect the cost of U.S. oil because all oil retailers (domestic and foreign) charge more. As long as the U.S. economy is tied to oil—and oil is traded globally—we will be susceptible to OPEC's market power and Persian Gulf instability. To date, the economic costs of oil dependence have been tremendous, totaling $7 trillion over the past 30 years by one estimate (Greene &Tishchishyna, 2000).

The political instability of the Persian Gulf has caused three major price shocks over the past 30 years. The Iraqi invasion of Kuwait in 1990 took an estimated 4.6 million barrels per day out of the global oil supply for three months. The Iranian revolution reduced global oil supplies by 3.5 million barrels per day for six months in 1979, and the Arab oil embargo eliminated 2.6 million barrels per day for six months in 1973 (EIA, 2001b). In each of these cases, the world oil supply dropped only about 5 percent (Davis, 2001), but world oil prices doubled or tripled (Greene et al., 1998). In the wake of these oil price hikes, U.S. inflation increased markedly, accompanied by downturns in our gross domestic product (BLS, 2001;BEA, 2001;EIA, 2001a). In each case, recession followed.

Petroleum imports also exact a toll on our international balance of trade: The $119 billion we spent on foreign oil in 2000 accounted for a fourth of that year's U.S. trade deficit (EIA, 2001c). The situation is likely to worsen as imports increase.

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[1] OPEC, the Organization of Petroleum Exporting Countries, consists of Algeria, Gabon, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, and Venezuela.

[2] UCS estimate based on the Energy Information Administration 's import cost figure of $119 billion in 2000 (EIA, 2001c).

Today, the United States imports over half the petroleum products we use; this portion can only rise as our oil appetite grows (Figure 2).

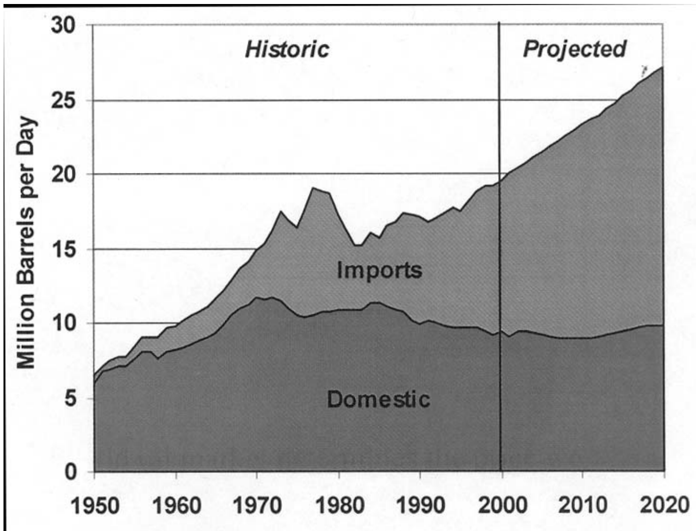

Figure 2. US Petroleum Supply, 1950–2020

Finally, consumers themselves feel a significant bite from our oil dependence. Forty percent of our daily oil consumption in 2000 (about 8 million barrels per day) went to fuel our cars and trucks, at a cost to consumers of $186 billion. By 2020, oil consumption is expected to grow by nearly 40 percent and consumers will be spending around $260 billion dollars per year to fuel up their cars and trucks.

Environmental Impacts

The cars and trucks we drive every day were responsible for over 20 percent of the global warming emissions produced by the United States during 2000: 1.5 billion tons (358 million metric tons, carbon equivalent) of the heat-trapping gases linked to global warming.[3] Most of these gases will stay in the atmosphere for more than 100 years, contributing to an increase in the earth's average surface temperature. This is projected to rise 2.5 to 10.4 °F (1.4 to 5.8 °C) between 1990 and 2100, if no major efforts are undertaken to reduce emissions of global warming gases. As the earth continues to warm, we face a great risk that the climate will change in ways that threaten our health, our economy, our farms and forests, beaches and wetlands, and other natural habitats.

Cars and trucks are also major contributors to air pollution. Regulations have helped clean up passenger vehicles over the past three decades. However, rising demand for travel and increased vehicle ownership will outpace even the standards on the books through this decade. Cars and trucks will need to clean up their act even more if we are to eliminate the threat air pollution poses to public health—especially to our children and the elderly.

Finally, producing and distributing the gasoline that went to fuel our cars and trucks in the year 2000 resulted in the emission of 848,000 tons of smog-forming pollutants and 392,000 tons of benzene-equivalent toxic chemicals, in addition to the pollutants emitted from the tailpipes of vehicles.[4] Altogether, cars and trucks are

[3] This UCS estimate is based on EIA 2000a. Each gallon of gasoline burned emits nearly 19 pounds of carbon dioxide, the primary pollutant responsible for global warming. The production and delivery of gasoline are responsible for another 5 pounds per gallon of global warming pollutants (Wang 1999).

[4] The production, refining, and delivery of each gallon of gasoline in the United States emit an estimated 6.4 grams (0.014 pounds) of smog-forming pollutants (Wang 1999). Upstream activities also release harmful toxic pollution into the air. This poses a major health hazard near refineries, along distribution routes, and at gasoline stations. For every gallon of gasoline deliv-

Continued

the largest single source of air pollution in most urban areas. As with U.S. oil use and global warming emissions, upstream air pollution is expected to continue to rise significantly over the next two decades, posing the greatest health threat to children, the elderly, and other vulnerable members of our population. Gasoline and oil distribution also leads to water and ground pollution and catastrophic oil spills such as the Exxon Valdez that harm the entire ecosystem.

A Comprehensive, Technology Based, Plan to Kick our Oil Habit

While the problems of our oil dependence loom large, there is a suite of technology options that can be used to turn things around. We can take advantage of the technical and engineering prowess of U.S. industries to put these technologies to work in a comprehensive approach that can ultimately move the transportation sector away from oil. No single silver bullet can solve the problems posed by our use of cars and trucks—but if we, as a society, choose now to invest in a variety of solutions, ranging from near to long term, together they can effectively eliminate the use of oil for transportation and at the same time address many of the other problems associated with our transportation system.

Because it will likely take most of the first half of this century to finally move ourselves off oil in the transportation sector, we must take advantage of every option that is afforded to us in that time. Conventional technologies can be put on the road over the next 10 years to dramatically reduce oil use from cars and trucks. Hybrid technology can then begin to actually stabilize that amount of oil below today's levels. Together, as shown in Figure 3, conventional and hybrid technology can fill the gap while the long-term hope offered by hydrogen fuel cells and alternative fuels begins to materialize.

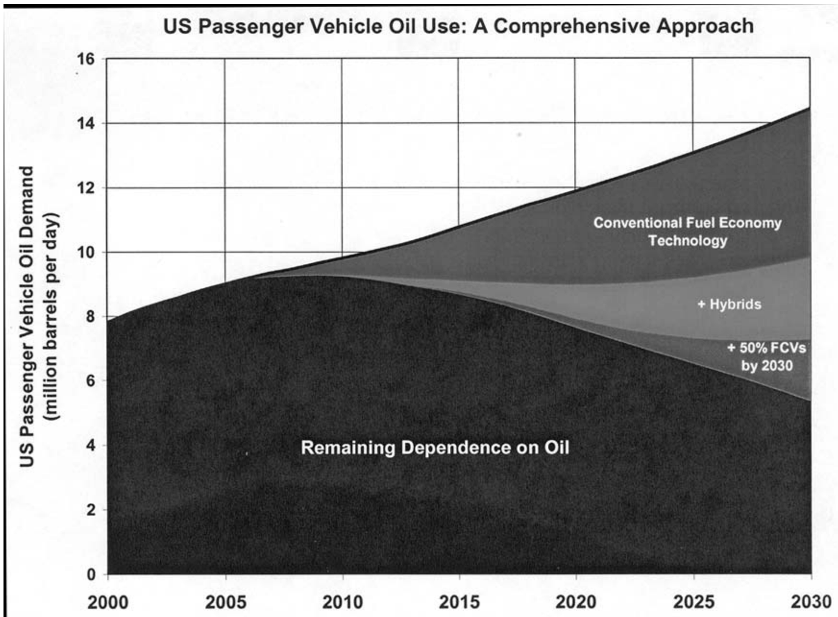

Figure 3. A comprehensive approach to reducing US passenger vehicle oil demand.

At the same time these technologies are being put into play to address oil dependence and energy security, they offer the opportunity to address the air quality and safety problems associated with cars and trucks. The aggressive use of conventional and advanced technology can mark a return to "the age of the engineer,"[5] as Ford's

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ered, 2.9 grams (0.0065 pounds) of benzene-equivalent toxic emissions are produced (Winebrake et al. 2000; Wang 1999).

[5] Robert B. Alexander, speech before the Management Briefing Seminars sponsored by the Michigan Chamber of Commerce and the University of Michigan (Traverse City, MI) August 4, 1977.

then Vice President of Car Product Development, Robert B. Alexander characterized the period in the late 1970's when automakers were challenged to provide consumers with more socially responsible vehicles by simultaneously improving safety, fuel economy, and emissions. The current and future levels of technology available in automobile development provide the exact same opportunity to both transform the internal combustion engine vehicles we have been driving for the past 100 years and to work on new technologies such as fuel cells and alternative fuels that offer the promise of addressing transportation problems in the longer run.

The technologies available today and those being developed for the future provide the opportunity to integrate air quality, safety, and reduced oil dependence into the regular redesign process that takes place for each car and truck model every 3–5 years. These three goals then become a complementary part of a refocused redesign process that can diminish and then ultimately kick our oil habit while also protecting public health through improved air quality, and making our highways safer. These technologies and this shift in focus are well within the abilities of our automobile and fuels industries, but will require a change in their priorities—a change that will need to be driven by clear signals from the government.

Like other investments in technology, using automotive technology to build a fleet of cleaner, safer, cars and trucks while reducing our oil dependence will be an engine for economic and job growth. For example, our analysis indicates that a reaching a fleet average of 40 mpg over the next ten years will provide consumers a net savings of more than $29 billion per year by 2015 because savings at the pump far outweigh the added vehicle costs. The money saved would be spent throughout the economy, yielding a net increase of 182,700 new jobs in areas such as the service industry, agriculture, construction, manufacturing and even 41,100 additional jobs for the U.S. auto industry and their suppliers.

The federal government can play a key role in addressing oil dependence while simultaneously helping to make our highways safer and improving air quality. Providing a clear vision that guides technology development to meet these goals can fulfill part of this role. This vision must capture the urgency of the problems while providing realistic goals, timelines, and performance metrics. Finally, the vision needs to include rolling up our sleeves and getting this technology on the road and be backed up by the necessary policies and resources to truly address the problems that exist today.

Conventional Technology

The most effective near term approach to addressing the many problems associated with our cars and trucks is to put existing and emerging convention technology to work. These technologies can reverse the 15 year trend of declining fuel economy and dramatically improve fuel economy over the next ten years—filling a stop-gap role by keeping keep passenger vehicle oil use near today's 8 million barrels per day, rather than letting it continue to grow at unprecedented rates.

Many of the technologies that could have been used improve fuel economy while making safer and cleaner vehicles have been left on the automakers' shelves. These technologies include efficient engines that incorporate lower friction components, variable valve technology, displacement on demand, gasoline direct injection, and turbo or super-charging. Improved transmission technologies have also been developed: e.g. 6-speed automatic transmissions with aggressive lock-up control, continuously variable transmissions, and efficient "manual" transmissions that are shifted by a computer instead of by the driver. Integrated starter/generator technology that can turn off the engine instead of letting it idle have seen use in Japan and Europe and are available to U.S. automakers. More mundane technologies can also be put to work: e.g. improved aerodynamics, lower rolling resistance tires, and electronic power steering.

Putting these technologies to work—according to our analysis and that of the National Academy of Sciences, researchers at MIT, and others—means that it is possible to make SUVs like the Ford Explorer that reach 34–35 miles to the gallon, family cars like the Ford Taurus that get up to 41–45 mpg, and full-size pickups like the Dodge Ram that can reach 30–33 mpg—all of which will have the same size, comfort, performance as consumers expect today along with the same or even improved safety (DeCicco 2001, Friedman 2001, NRC 2002, Weiss 2000). The added technologies will increase vehicle cost, but will more than pay for themselves in gasoline savings.

Another conventional engine technology that could be used to address oil dependence is diesel technology, sometimes referred to as "advanced lean burn" technology. Diesel engines offer improved efficiency and, like gasoline vehicles, rely on fuel derived from oil. In many ways, diesel is no different from the other conventional technologies that can be used to improve fuel economy and should be treated within the policy arena in the same way as the other conventional technologies listed above.

Several cautions are in order, however, on diesel:

1. Diesel technology is expensive and will not be as cost effective as other conventional technologies. The added costs needed to reduce the production of harmful emissions will further reduce the cost effectiveness of diesel technology.
2. Unlike the conventional technologies above, diesel makes it harder to address public health concerns regarding air quality. Current diesel technology in Europe is cleaner than past vehicles, but still produces toxic emissions and smog forming emissions that several times dirtier than the average gasoline cars and trucks under Federal Tier 2 emission requirements.
3. With added emission controls being developed by the auto industry, we expect that diesel vehicles will fall within the allowance of future U.S. emission standards, but are unlikely to catch up with the cleanest gasoline cars. Conventional gasoline vehicles can already meet standards well below those required by current law, while diesel vehicles are expected to qualify within the dirtier emission categories under Tier 2, making it harder to address air quality concerns.
4. Questions remain about whether future standards on the books are sufficient to protect public health, but even with a clean bill of health, diesel may not be as cost effective a fuel economy strategy as employing existing and emerging conventional gasoline technology.

With those cautions noted, and as long as diesel is held to the same standards as gasoline vehicles and provided with the same incentives as other conventional technology, it can still be part of the mix of conventional technologies being considered.

The main historical approach to getting conventional technologies on the road has been through fuel economy standards; which have proven quite effective—saving 43 billion gallons of gasoline in the year 2000, or a reduction of over 25 percent, according to recent work by the National Academy of Sciences (NRC 2002). The current effort on fuel economy is a proposal by the National Highway Traffic Safety Authority (NHTSA) to increase the fuel economy standard for light trucks by 1.5 mpg as of model year 2007, raising it from 20.7 mpg to 22.2 mpg.

While NHTSA's proposed rule would be the first increase in fuel economy standards in a decade, it is an extremely modest goal given the suite of technologies available in that timeframe and will not pose a challenge to automakers. It will also have a negligible impact on our oil use, saving less than one day's worth of oil each year between 2005 and 2008. Over that timeframe our cumulative oil use will be more than 30 billion barrels of oil compared to cumulative savings from the NHTSA proposal that amount to 0.02 to 0.06 billion barrels of oil from 2005 to 2008. Significantly more can be done with the use of conventional technology and we hope that NHTSA will take greater advantage of this in their final rule. We also hope that NHTSA or Congress will address many of the regulatory loopholes within existing fuel economy regulations that are adding to our increased oil dependence.

Additional approaches can be taken by the government to support of near term technology. Although choice is severely limited in today's car and truck market, the government can commit to purchasing the highest fuel economy car or truck that meets their needs and increasing the overall fuel economy of federal fleets. In this way the government can both provide the auto industry with a guaranteed market for vehicles that use conventional technology to improve fuel economy while also providing leadership by example. Government can also provide incentives for the purchase of cars and trucks with above average fuel economy.

Advanced Technology

More recent developments have led to a new suite of technologies that can follow on the heels of the conventional technology improvements discussed above. These include the development of hybrid electric vehicles, hydrogen fuel cell vehicles, and dedicated alternative fuel vehicles.

Hybrid Electric Vehicle Technology provides fuel economy improvements primarily during city driving, with the ability to more than double city fuel economy while providing incremental benefits on the highway. Creating a hybrid entails the use of an electric motor and battery along with a conventional internal combustion engine. The electric motor provides regenerative braking that recovers energy in stop and go traffic, idle off capability that turns the engine off when you would otherwise be wasting fuel at a stop light, and electric motor assist that provides the necessary boost for driving around town and accelerating onto the highway. Analysis in our recent report on hybrids indicates that a fleet of hybrid cars and trucks could reach 50 to 60 miles per gallon (Friedman, 2003). Hybrids will also provide added features that will appeal to consumers: such as improved low-end torque, smoother acceleration when using the electric motor, reduced engine and brake maintenance and added electrical capacity.

Honda and Toyota have both offered first-generation hybrid cars in the marketplace for the past few years and Toyota recently announced its second generation Prius that achieves better fuel economy while also providing more space and better acceleration. Ford and GM are planning to join the hybrid market with SUVs in 2004 and 2005, while Toyota is expected to offer a luxury hybrid SUV that will outperform the conventional model. Fully developed gasoline hybrid electric technology, technology that builds on the benefits of improved conventional vehicles, offers the potential to begin reducing passenger vehicle oil use below today's 8 million barrel per day level during the next decade while meeting the strictest existing Federal tailpipe emission levels, Bin 2.

Hybrids will cost more than conventional vehicles, especially in the early years when production volumes are low and automakers are unable to take advantage of economies of scale. Once sufficient production volumes are reached, automakers will be able to sell hybrids for a profit while consumers save more on gasoline than they spent for the added technology—a win/win situation. The challenge with hybrids is how to reach those economies of scale as soon as possible. Hybrids can benefit from tax credits and other financial incentives to encourage consumers to purchase the early hybrid offerings. These tax credits must incorporate emissions and fuel economy performance metrics to ensure that taxpayer dollars are spent on the most promising technology—hybrids that can provide consumers with the greatest gasoline savings and cleanest air. Without the assurance that hybrid tax credits are going to vehicles that perform better than the average vehicle on the road, such a program would run the risk of following in the footsteps of the Arizona budget crisis that was created by offering tax breaks to alternative fuel vehicles without requiring environmental performance metrics.

The goal of hybrid tax credits would be to get the technology on the road and help familiarize consumers with a new vehicle option. Getting hybrids on the road in significant numbers also has the benefit of supporting fuel cell vehicles as they both share many of the same electric technologies. Hybrid tax credits will not guarantee oil savings or improvements in energy security, but they will help to pave the road for those benefits to be realized in the future.

As with some of the conventional technology mentioned, a note of caution is also required regarding some vehicles that may end up being labeled by some as hybrids:

1. Of specific concern are vehicles that use the 42 volt integrated starter/generator, or idle-off, technology mentioned in the conventional technology section. This is a wonderful conventional technology that can provide fuel economy improvements of more than 10 percent, but as noted above, hybrids provide more than just idle-off capability and the two technologies should not be confused when establishing policies and providing incentives for hybrid technology. If treated like hybrids instead of conventional technology, these idle-off systems have the potential to repeat the problems of the Arizona budget crisis on a national scale.
2. Of additional concern are vehicles that use hybrid technology to increase the weight and power of a vehicle without providing fuel economy benefits. These "muscle hybrids" represent a squandering of hybrid technology and are reminiscent of past technology trends where conventional fuel "efficiency" technology was used to make vehicles heavier instead of helping them to get better fuel economy. Policies must also recognize that the label "hybrid" does not inherently imply improved fuel economy performance.

Hydrogen Fuel Cell Vehicle Technology offers the ultimate potential of complete energy independence, dramatic reductions in greenhouse gas emissions and zero tailpipe emissions. Fuel cells combine hydrogen with oxygen in the air to produce electricity, water, and some heat. If the hydrogen is stored on-board the vehicle, no smog forming emissions, carbon dioxide or toxic pollutions are emitted from the tailpipe. Hydrogen fuel cell vehicles can also provide a smooth, quite and comfortable ride possible with electric drive technology. Fuel cells can also be used for many other things, from powering laptop computers to providing the electricity for a hospital, home or office building.

To be successful, fuel cell vehicles will rely on many of the conventional and hybrid technologies reaching the consumer market before fuel cells—therefore efforts made by automakers on conventional and hybrid vehicles will also pay off in the scope of their longer term fuel cell vehicle development. Many of the same conventional technologies that would help today's cars and trucks reach 40 miles per gallon, e.g. improve aerodynamics and reduce rolling resistance, along with the high strength materials that can make vehicles both lighter and safer, will help to fuel cell vehicles efficient and cost effective. The technology for the electric motors, batteries and electric auxiliary systems in hybrid vehicles will be used in the same roles to make fuel cell vehicles work.

Fuel cell vehicles, however, will not be ready in the same timeframe as existing conventional technologies or even hybrid vehicles. Without sufficient government support, it will probably take more than 20 years for millions of fuel cell vehicles and the necessary hydrogen fuel to be offered to consumers. It will take even longer, with business as usual, for the majority of the hydrogen to be supplied by renewable energy sources. If hydrogen fuel cell vehicles are going to be widely available in the marketplace within the next 10 to 15 years, a government program on the scale of the Apollo project will be necessary. And even with such an aggressive program, fuel cells must still be considered a long-term investment, needing to be supported by the shorter-term investments of getting conventional, hybrid and alternative fuel technology on the road.

As with the Apollo project, a similar program to support hydrogen fuel cell vehicles must have a clear development target. The engineers knew what they were shooting for: putting a man on the moon and getting them back safely by the end of the decade. That meant they needed to develop the technology to build a rocket that could put a human on the moon and then make it happen within a certain amount of time. For today's automotive engineers to know what is being asked of them on hydrogen fuel cell vehicles the parallel set of goals would be as follows: develop the technology to build a fleet of a safe, clean, efficient and cost effective hydrogen fuel cell vehicles; develop the technology to provide a clean, cost effective source of hydrogen; and then make it happen within the next 15 years. Developing the technology is not enough; a fuel cell vehicle "Apollo-like" project must also include clear vehicle production and fuel supply goals, performance targets and timelines along with the resources to make the program successful.[6]

A final note of caution regarding fuel cell and hydrogen technology: just because a fuel cell vehicle runs on hydrogen, it should not be assumed that it is clean. Hydrogen can be made from many feedstocks and is actually considered an energy carrier and not an energy source, or fuel, in and of itself. In that way, it is much like electricity; its overall energy and environmental benefits are linked to the fuel or energy source used to make the hydrogen in the first place. For that reason it is important that funding for hydrogen and funding for renewable energy go hand in hand. Renewable resources such as wind, solar and biomass energy will be vital in making the clean hydrogen future a reality. Cuts in renewable funding jeopardize investments in hydrogen and fuel cells.

Alternative Fuels offer the promise of 100 percent oil displacement, often along with significant air quality benefits. In the long term, alternative fuels based on renewable, home grown agricultural waste and dedicated crops can be one of the backbones of clean, domestic energy production—even supplying some of the hydrogen that can be used in fuel cell vehicles. In the nearer term, alternative fuels such as natural gas can serve both as an alternative to diesel in heavy duty vehicles and as a bridge to hydrogen fuel cells (both by helping to develop technology to support the use of gaseous fuels and by providing a key early feedstock for hydrogen). Alternative fuel support can also help domestic industries that provide fuel options that can move us off of oil.

Much like hybrids, one of the hurdles alternative fuels face is their high cost in low volume production along with the initial costs of building the necessary infrastructure. And again, much like hybrids, tax credits for alternative fuel vehicles, fuel, and infrastructure can help to build the necessary economies of scale. Many other incentive programs are also possible, though clear enforcement mechanisms are vital to their success.

It is important, also, to recognize some of the technical limitations associated with some alternative fuel approaches. Vehicles that could run on an alternative fuel are not providing energy security or environmental benefits if they are actually being run on gasoline or diesel, both of which are clearly derived from oil and are not alternative fuels. Thus targeting any incentives to directly encourage and reward alternative fuel use can both help to ensure growing markets for the alternative fuels and provide the associated benefits.

[6] For reference, President Kennedy asked for $531 million in fiscal year 1962 alone to support the Apollo program, today that would be equivalent to more than 3 billion dollars in the FY 2004 budget.

Conclusion

The United States has a history putting technology to work in solving many of the problems around us. We developed mass-production, computers, the Internet, and we put several people on the moon. We now have the technology to put people into cars and trucks that don't guzzle so much gas and can further develop the technology to put them in cars and trucks that don't use gasoline at all.

As an engineer, I see the broad array of available technology as an opportunity to roll up our sleeves and get to work making vehicles safer, cleaner and less dependent on oil while saving consumers money and creating new jobs. We can rely on existing conventional technology over the next ten years to take advantage of this opportunity. At the same time, we can make investments in hybrid vehicles, alternative fuels, and hydrogen fuel and fuel cell vehicles to take advantage of the longer-term opportunities. Because these conventional and advanced technologies compliment each other, it is not an either/or proposition. And because our need for safe vehicles, clean air and increased energy security is so important and immediate we cannot afford to these technologies and the opportunities they represent slip through our fingers. The Federal Government has a key role to play in developing sound policies to ensure that we take advantage of these opportunities.

Thank you for the opportunity to testify before the Committee today. I would be happy to answer any questions you may have.

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Senator BROWNBACK. Thank you, Dr. Friedman.

Mr. McCormick, thank you for joining us.

STATEMENT OF J. BYRON McCORMICK, EXECUTIVE DIRECTOR, FUEL CELL ACTIVITIES, GENERAL MOTORS CORPORATION

Mr. McCORMICK. Thank you, Senator. I appreciate the opportunity to be here today to testify on behalf of General Motors.

As you noted, I'm Byron McCormick, the Executive Director of General Motors' Global Fuel Cell Activities, and I head the team that is developing hydrogen fuel cell vehicles that people want to drive and, most importantly, want to buy.

Senator BROWNBACK. Mr. McCormick, pull that microphone a little——

Mr. McCORMICK. Oh, I'm sorry.

Senator BROWNBACK. —closer to you, if you would.

Mr. McCORMICK. Before I go into my prepared text, I'd like to make a couple of additions.

First of all, you may have noticed today that we made an announcement, a business announcement, with Dow Chemical. We think it's a milestone in moving towards the hydrogen economy, and it's somewhat different than many of the things that people talk about.

Dow and General Motors today entered into an agreement with a plan to use byproduct hydrogen generated in their chemical production facilities in Texas and other places in the world with General Motors using its automotive fuel cells to create electricity from that byproduct hydrogen to, in fact, then help power the facilities themselves. It's a pure business proposition and one that we think makes a great deal of sense but, for us, allows us to move the technology out of the laboratory into low-volume production where we'd begin to develop our supply base, et cetera.

The second thing I'd like to mention before I go into my larger discussion is that we'd like to invite the members and their staff this afternoon. We have, at the exit of the building, hybrid and fuel cell vehicles which will be available for ride and drive. And over the next 2 years, we will have hydrogen fuel cell vehicles here in Washington, DC, available for you to drive and your staffs to drive, and you can contact our Washington office so you can get some hands-on experience with the technology.

Now, as I comment, this is a really exciting time for the automotive industry and for General Motors, in particular. Technology is changing the way we live our lives for the better, and there's much more to come. This year we announced a three-phased advanced technology plan focused on reducing consumption in vehicle emissions. This plan includes internal combustion engine initiatives such as displacement on demand, cylinder deactivation, and many other activities, as well as a suite of high-volume hybrid offerings for the mid-term. And these hybrids are really designed to match the driving patterns of U.S. consumers and, in fact, are on most of our best-selling vehicles, and then, early next decade, to be ready to introduce hydrogen fuel cell vehicles.

The subject today is hydrogen in fuel cells. And these technologies, when they're fully developed and deployed will not only deliver revolutionary vehicles, like the Hy-Wire vehicle, which we will be showing at RFK Stadium, if you have a chance to see it this week, but also will change the way we think about the automobile and our environment.

We are on the threshold of a historic opportunity. Instead of the historical evolution of automotive technology by incremental improvements, we now see our way to bold technology advances that will fundamentally change personal transportation in this century. These advances have the potential to lead to the creation of commercially viable, zero-emission, fuel cell vehicles with the functionality that Americans expect. This vision is based on hydrogen as fuel, which can be made from many nonpetroleum sources.

Not only will fuel cells essentially remove the auto from the environmental debate by reducing tail pipe emissions to only water vapor and potentially shifting vehicles to renewable fuels, they will also offer the performance for every type of vehicle—heavy-duty commercial, sport utilities, truck, mass transit, or cars.

Fuel cells running on hydrogen fuel are the ultimate environmentally friendly vehicles, because their emission is only water. The fuel cell supplies the electricity to electric motors, which power the wheels. The fuel cell produces electricity by stripping electrons from the hydrogen that travels through a membrane and combines with oxygen to form water. Fuel cell vehicles are substantially more efficient than internal combustion engine vehicles, have no pollution, and are quiet.

Beyond the advantages for the vehicles, fuel cells promise two additional benefits. First, once integrated into our daily lives, fuel cell vehicles will be supported by broadly available cost-effective hydrogen refueling infrastructure. And I'm sure we'll want to talk more about that as we go forward. Such an infrastructure, by its very nature, would provide an evolutionary shift of personal transportation from petroleum to, very importantly, a mix of sources, including renewables.

Secondly, the development of this technology will create new, more environmentally compatible distributed electric power generation capabilities, like the type we announced with Dow this morning. The automobile will have the potential to provide electric power for homes and work sites, as well.

The power on today's electrical grid could be supplemented by generating capacities of cars in every driveway. For example, if only one out of 25 cars in California today was a fuel cell vehicle, their generating capacity would exceed the entire utility grid. A typical mid-sized fuel cell vehicle produces 50 to 100 kilowatts, and typical household power is on the 7 to 10 kilowatts load. So you can see that one vehicle can really power a neighborhood.

Like any advancement that has promise to completely change the dominant technology, fuel cell development is a major costly technical endeavor which, if aggressively undertaken and sustained, should allow significant implementation in the 10- to 20-year time frame. Our rate of progress today is rapid. With an uninterrupted focus, our technology momentum should make this vision possible.

It is clear that we are in intense global competition for leadership in this race to establishing commercialized fuel cell technologies. In Japan, the kyogikai, which are companies operating under government auspices, are developing a program for the implementation of fuel cell technology. Now is the time for U.S. Government and U.S. industry to create a partnership that can lead to the changed world that we see in this vision.

Recognizing this potential, approximately 6 years ago General Motors consolidated and accelerated its fuel cell program. We were given one mandate by our management: Take the automobile out of the environmental debate regardless of whether the environmental debate is focused on air quality, climate, or overall sustainability. GM leadership recognizes that the global conditions inspire bold and thoughtful action.

Number one, there are over 6 billion people in the world, with 10 billion expected later this century. Most of these people are young, globally aware, Web-connected, and, most importantly, residing in emerging economies with escalating demands for personal transportation. Only 12 percent of the world's population have automobiles today. That's a staggering number, 88 percent nonpenetration of automobiles in the world today. Therefore, a breakthrough in energy efficiency and emissions will absolutely be required to meet the demands of a future sustainable high-quality environment.

Our vision is as follows. We see fuel cells as the long-term power source. The GM Global Fuel Cell Program seeks to create affordable, full-performance fuel cell vehicles that meet customer preferences and demands and emit only water from their tailpipes. We see hydrogen as the long-term fuel. And the creation of a robust, readily available, hydrogen refueling network for those vehicles must be accessible through refueling stations as gasoline is dispensed today.

The hydrogen in the infrastructure could be certainly derived from a mix of hydrocarbons and any source of electricity. In the first case, hydrogen is extracted from petroleum, natural gas, a renewable hydrocarbon, such as ethanol, via reformers or fuel processors, which catalytically decompose the hydrocarbons into hydrogen carbon dioxide. Hydrogen can also be extracted from water using electrolysis, which uses electricity to dissociate water. Electricity could come from conventional power plants, renewable power such as hydro, solar, wind, or geothermal sources. And in this way, the hydrogen economy allows a graceful transition for transportation from a reliance on petroleum to a robust diversity of energy sources, including renewable.

The blending of these energy sources is seamless to the driver of the vehicle. The driver of the vehicle really only sees the hydrogen in fuel and not whether it came from petroleum, natural gas, nuclear, or renewable. And we should point out that hydrogen can be created directly from nuclear energy, as well.

There are major challenges we need to overcome to make this hydrogen economy a reality. First, we need continued development of onboard hydrogen storage. Using hydrogen in a vehicle requires a completely new type of tank. The challenge is to find a lightweight, compact tank that stores enough hydrogen at modest pressures for a lengthy drive.

Liquid hydrogen stored cryogenically or compressed hydrogen stored at high pressures will suffice for early market introductions. But, over the long term, we should seek solid, in quotes, storage techniques such as chemical hydrides, which will more efficiently and cost-effectively store significant amounts of hydrogen onboard the vehicle.

We need the Government to partner with us on fundamental long-term research and development of hydrogen storage, as well as a full portfolio of technologies.

And that includes our second major challenge to a hydrogen economy, developing and commercializing clean and efficient methods of producing hydrogen. Eventually, we want to use methods that are renewable and have no adverse environmental impact.

We're working closely with energy suppliers to investigate the best solutions. A few weeks ago, we announced that we are partnering with Shell to demonstrate our fuel cell vehicles here in Washington, DC, and Shell will be putting a hydrogen fueling station in the District to be operational in the October time frame so that people can begin to experience hydrogen as a real fuel.

The third challenge we have to overcome is developing business models for the deployment of the hydrogen infrastructure and piloting technologies to support it.

As for the reality of the vision, we, at General Motors, have invested aggressively in what we call enabling technologies—fuel cells, reformers, electrolyzers, and automotive electric propulsion. Our commitment is clear in the significance of our investment—hundreds of millions of dollars annually for several years to date, and growing. The acceleration has spurred some very rapid technical progress.

To give you an idea of that rate of progress, in the last 4 years the size and weight of our fuel cell stack for a given power has decreased by a factor of 10. And we have also achieved significant cost reduction with each new generation of stack technology. In fact, we generate new generations a couple to three times a year.

Like today's gasoline cars, fuel cell vehicles must be able to handle a tremendous range of environmental conditions. We are now able to start fuel cells in freezing, down to minus 40, and do it in substantially less than a minute. Also, at the vehicle level, we have developed and demonstrated full-performance vehicles, like our HydroGen3 vehicles that you will be able to drive later today.

We have developed revolutionary auto designs such as our AUTOnomy concept, Hy-Wire concept, which combine fuel cells, and by-wire electronics, and other advanced technologies in new and unique ways. These designs could make fuel cell vehicles both more affordable and, most importantly, more compelling to our customers.

Additionally, we have demonstrated numerous stationary, distributed electrical-generation systems based on our fuel cell technologies.

These milestones represent remarkable progress, and our rate of progress encourages us. But no one should overlook that there remain major technical obstacles that must be conquered before vehicles can be brought to market and become commercially successful.

Let me be clear about the progress represented by our demonstration vehicles. The progress is rapid and encouraging, but we are not there yet. Although we are well on our way to achieving automotive performance levels required for reliability, durability, and safety, and full capability in harsh weather extremes, including the ability to withstand environment and in-use abuse that trucks and automobiles are subject to worldwide every day. We must achieve these goals and, most importantly, do it in a way that is affordable to our customers.

Achieving full automotive performance and affordability targets is the key to customer acceptance and enthusiasm. These targets require a huge investment and can only reasonably be made if we believe the infrastructure will be there to allow us to introduce fuel cell vehicles to the public.

And I want to emphasize the next sentence. Consistent and sustained government policy today must drive the development of the hydrogen economy by accelerated R&D in hydrogen storage, pilot-scale distribution networks, fuel cell stations, and, most importantly, incentives for proliferation.

Selective demonstration vehicles or captive fleets will not suffice to encourage major timely investment by energy producers or automotive companies, nor will potential creators of the hydrogen infrastructure invest until they see a rapid expansion in fuel cell hybrid vehicles. Even then, there is an economic burden of supporting the infrastructure during the long transition period from today's gasoline-powered fleet.

Stewardship of this transition requires a careful and thoughtful, well-thought-out plan which allows automotive manufacturers, our materials and component suppliers, hydrogen fuel suppliers, and government regulatory bodies to progress hand in hand. This careful coordination must also take into account technical, financial, and environmental realities that a successful transition requires. This is the basis on which a government-industry partnership must be based.

Within General Motors, the magnitude of our fuel cell investment creates an intensive business dilemma. The choice between using our resources to meet expanding funding needs to achieve the revolutionary vision at the expense of short-term initiatives, or to fund an aggressive pursuit of more incrementally based technologies. To a large degree, the outcome of that internal debate in General Motors will depend on the development of a long-term, stable set of governmental policies and initiatives upon which we can properly balance the investment of our finite financial and technical resources.

As a closing thought, I believe that fuel cells and hydrogen-based transportation are absolutely the future. The pace of technical progress is accelerating. We cannot be left behind or sitting on the sidelines. Now is the time for the U.S. Government and U.S. industry to create a partnership that can lead to the world which we have envisioned.

General Motors and our partners are driving to bring the first-generation fuel cell technology to market as rapidly as possible. To a large degree, this initiative was made possible by the pioneering research and development sponsored by NASA and later extended by the Department of Energy. We now look forward to not only realizing the full benefits of that pioneering work in automobiles, but additionally in working together with the Government to create new generations of breakthrough technologies in hydrogen storage and fuel cell materials.

Thank you, and I look forward to your questions.

[The prepared statement of Mr. McCormick follows:]

PREPARED STATEMENT OF J. BYRON MCCORMICK, EXECUTIVE DIRECTOR, FUEL CELL ACTIVITIES, GENERAL MOTORS CORPORATION

I appreciate the opportunity to be here today to testify on behalf of General Motors. I am Byron McCormick, Executive Director of GM's Global Fuel Cell Activities. I head the team that is developing hydrogen-powered fuel cell vehicles that people will want to drive and buy.

This is an exciting time in the automotive industry and for General Motors. Technology is clearly changing the way we live our lives for the better, and there's more to come. This year, we announced a three-phase advanced technology plan focused on reducing fuel consumption and vehicle emissions. This plan includes advanced internal combustion engine initiatives—such as Displacement on Demand cylinder deactivation—for the near term; a suite of high-volume hybrid offerings for the mid-term, and the introduction of hydrogen fuel cell vehicles early next decade.

The subjects today are hydrogen fuel and fuel cells. These technologies, when fully developed and deployed, will not only deliver revolutionary vehicles, but will change the way we think about the automobile and our environment.

We are on the threshold of an historic opportunity. Instead of the historical evolution of automotive technology by incremental improvements, we now see our way to bold technology advances that will fundamentally change personal transportation for the new century. These advances have the potential to lead to the creation of commercially viable zero-emission, fuel-efficient fuel cell vehicles with the functionality that Americans expect. This vision is based on hydrogen fuel, which can be made from many non-petroleum energy sources. Not only will fuel cells essentially remove the auto from the environmental equation by reducing tailpipe emissions to only water vapor and potentially shifting vehicles to renewable fuels—they will also offer the performance required for every type of vehicle: heavy duty commercial, sport utilities, trucks, mass transit or cars.

Fuel cell vehicles running on hydrogen fuel are the ultimate environmentally friendly vehicles because the only emission is water. The fuel cell supplies electricity to an electric motor that powers the wheels. The fuel cell produces electricity by stripping electrons from hydrogen that travels through a membrane to combine with oxygen to form water. Fuel cell vehicles are more than twice as energy efficient as the internal combustion engine, have no pollutant emissions, and are quiet.

Beyond the advantages for vehicles, fuel cells in vehicles promise two additional benefits. First, once fully integrated into our daily lives, fuel cell vehicles will be supported by a broadly available, cost-effective hydrogen-refueling infrastructure. Such an infrastructure by its very nature would provide an evolutionary shift of personal transportation from petroleum to a mix of energy sources including renewables.

Secondly, the development of this technology will create new, more environmentally compatible distributed electric power generation possibilities. The automobile will have the potential to provide electrical power to homes and worksites. Power on today's electrical grid could be supplemented by the generating capacity of cars in every driveway. For example, if only one out of every 25 cars in California today was a fuel cell vehicle, their generating capacity would exceed that of the utility grid. A typical midsize fuel cell vehicle would produce 50 to 75 kilowatts of electrical power, where a typical household may use 7 to 10 kilowatts at peak load.

Like any advancement that has the promise to completely change the dominant technology, fuel cell development is a major, costly, technical endeavor, which—if aggressively undertaken and sustained—should allow significant implementation in the 10–20 year timeframe. Our rate of progress today is very rapid. With an uninterrupted focus, our technological momentum should make this fuel cell vision possible.

It is clear that we are in an intense global competition for leadership in this race to establish and commercialize fuel cell technologies. Toyota, Honda, Daimler, Ford, Volkswagen, Nissan, PSA, Hyundai, GM and others all have large programs. In Japan, the kyogikai, which are companies operating under government auspices, are developing a program for the implementation of fuel cell technology. Now is the time for the U.S. government and U.S. industry to create a partnership that can lead the world in the charge to achieve this vision.

Recognizing this potential, approximately six years ago at General Motors fuel cell activities were consolidated and accelerated. We were given one mandate by our management: Take the automobile out of the environmental debate. Regardless of whether the environmental debate is focused on air quality, climate, or overall sustainability, GM leadership recognizes that global conditions inspire bold, thoughtful action.

1. There are over 6 billion people in the world today with over 10 billion expected later this century. Most of these people are young, globally aware, web-connected, and residing in emerging economies with escalating demand for personal transportation.
2. Only 12 percent of the world's population have automobiles today. Therefore, a breakthrough in energy efficiency and emissions will be required to meet the demands of the future in a sustainable high-quality environment.

Our vision is as follows:

1. We see fuel cells as the long-term power source. The GM global fuel cell program seeks to create affordable, full-performance, fuel cell-powered vehicles that meet customer preferences and demands and emit only water vapor from their tailpipes.
2. We see hydrogen as the long-term fuel. The creation of a robust, readily available hydrogen-refueling network for those vehicles will be accessible through refueling stations, as gasoline is dispensed today. Hydrogen in the infrastructure could be derived from a mix of sources including: 1) hydrocarbons, and 2) from any source of electricity.

In the first case, hydrogen is extracted from petroleum, natural gas and renewable hydrocarbons, such as ethanol, via "reformers" or fuel processors, which catalytically decompose the hydrocarbons into hydrogen and carbon dioxide.

Hydrogen can also be extracted from water using electrolysis, which uses electricity to dissociate water. Electricity would come from conventional power plants or renewable power such as hydro, solar, wind, and geothermal sources. In this way, hydrogen fuel allows a transition of transportation from reliance on petroleum to a robust diversity of energy sources including renewable energy. The blending of these energy sources is seamless to the driver of a vehicle; he sees only hydrogen fuel, not whether it came from petroleum, natural gas, nuclear or renewable energy. Hydrogen created directly from nuclear energy is also a future option.

There are three major challenges that we need to overcome to make this hydrogen economy a reality:

First, we need continued development of on-board hydrogen storage. Using hydrogen in a vehicle requires a completely new type of fuel tank. The challenge is to find a lightweight, compact tank that stores enough hydrogen at modest pressure for a lengthy drive.

Liquid hydrogen stored cryogenically or compressed hydrogen stored at high pressures will suffice for early market introduction, but, over the long term, we should seek "solid" storage techniques such as chemical hydrides, which will more efficiently and cost-effectively store significant amounts of hydrogen on board the vehicle.

We need the government to partner with us on fundamental, long-term research and development on hydrogen storage as well as a full portfolio of technologies.

And that includes our second major challenge to a hydrogen economy—developing and commercializing clean and efficient methods of producing hydrogen. Eventually, we want to use methods that are renewable and have no adverse environmental impact. We're working closely with energy suppliers to investigate the best solutions. A few weeks ago, we announced that we are partnering with Shell to demonstrate our fuel cell vehicles and an operational hydrogen fueling station here in Washington, DC. The demonstration vehicles went into service today and the fueling station will be operational in late fall.

The third challenge we have to overcome is developing business models for the deployment of a hydrogen infrastructure and piloting technologies to support it.

As for the reality of this vision, we at General Motors have invested aggressively in what are called "enabling" technologies: fuel cells, reformers, electrolyzers and automotive electric propulsion. Our commitment is clear in the significance of our investment—over $100 million annually for several years to date, and growing. The acceleration has been spurred on by rapid technical progress.

To give you an idea of that rate of progress, in the last four years the size and weight of our fuel cell stack for a given power has decreased by a factor of 10. And we have also achieved a cost reduction with each new generation of stack technology.

Like today's gasoline cars, fuel cell vehicles must be able to handle a tremendous range of environmental conditions. We are now able to start fuel cells from freezing—minus 40 °C—in substantially less than a minute. Also at the vehicle level, we have developed and demonstrated full-performance vehicles like our HydroGen3 demonstration vehicles that you will be able to drive here in Washington. And we have developed revolutionary designs, such as our AUTOnomy concept and Hy-wire prototype vehicles, which combine a fuel cell, by-wire electronics, and other advanced technologies in new and unique ways. These designs could make fuel cell vehicles both more affordable and more compelling for our customers.

Additionally, we have demonstrated numerous stationary, distributed electrical-generation systems based on our fuel cell technologies.

These milestones represent remarkable progress. Our rate of progress encourages us, but it is crucial to recognize that the race for fuel cell development is a marathon, not a sprint. No one should overlook that there remain major technical obstacles that must be conquered before these vehicles can be brought to market and can become commercially successful.

Let me be clear about the progress represented by our fuel cell demonstration vehicles. The progress is rapid and encouraging, but we are not there yet. Although we are well on the way to achieving automotive performance levels required for reliability, durability, safety and full capability in harsh weather extremes, including the ability to withstand all environment and in-use abuse that automobiles and trucks worldwide are subjected to every day. We must achieve these goals and, more importantly, affordability before this technology will be considered an option by our customers.

Achieving full automotive performance and affordability targets is key to customer acceptance and enthusiasm. These targets require huge investments that can only be responsibly made if we believe the infrastructure will be there to allow us to introduce fuel cell vehicles to the public. Government policy today must drive the development of the hydrogen economy by accelerated R&D in hydrogen storage, pilot-scale distribution networks, and refueling stations and incentives for their proliferation.

Selective demonstration vehicles or captive fleet tests will not suffice to encourage major timely investment by the energy producers and the full automotive supply base before a hydrogen infrastructure is seen to be evolving. Nor will potential creators of the hydrogen infrastructure invest until they see a rapid expansion of hydrogen fuel cell vehicles and even then, there is the economic burden of supporting that infrastructure during the long period of transition from today's gasoline-powered fleet.

Stewardship of this transition requires a carefully thought out plan which allows the automotive manufacturers, their material and component suppliers, the hydrogen fuel providers and governmental regulatory bodies to progress hand-in-hand. This careful coordination must also take into account the technical, financial and environmental realities that a successful transition requires.

This is the basis on which a government-industry partnership must be based.

Within General Motors, the magnitude of our fuel cell investment creates an intense business dilemma-the choice between using our resources to meet the expanding funding needs to achieve a revolutionary vision at the expense of short-term focused initiatives, or to fund the aggressive pursuit of more incrementally focused initiatives.

To a large degree, the outcome of that internal debate will depend on the development of a long-term, stable set of governmental policies and initiatives upon which we can properly balance the investment of our finite financial and technical resources.

As a closing thought, I believe that fuel cells and hydrogen-based transportation are the future. The pace of technical progress is accelerating. We cannot be left behind or sitting on the sidelines. Now is the time for the U.S. government and U.S. industry to create a partnership that can lead the world in the charge to achieve this vision.

General Motors and our partners are driving to bring first-generation fuel cell technology to market as rapidly as possible. To a large degree, this initiative was made possible by pioneering R&D work sponsored by NASA and later extended by the Department of Energy. We now look forward to not only realizing the full benefits of that pioneering work in automobiles, but, additionally, working together with government to create new generations of breakthrough technologies in advanced hydrogen storage and fuel cell materials.

Thank you.

I look forward to responding to your questions.

Senator BROWNBACK. Thank you, Mr. McCormick. This is very encouraging testimony.

Mr. Preli?

Mr. PRELI. Preli.

Senator BROWNBACK. Very good to have you here today.

STATEMENT OF FRANCIS R. PRELI, JR., VICE PRESIDENT-ENGINEERING, UNITED TECHNOLOGIES CORPORATION FUEL CELLS

Mr. PRELI. Good afternoon Mr. Chairman, Senator.

My name is Frank Preli. I'm vice president of engineering for UTC Fuel Cells, a business of UTC Power, which is a division of United Technologies Corporation. I appreciate the opportunity to participate in today's hearing.

UTC Fuel Cells is one of the largest and most experienced fuel cell companies in the U.S. and the world. We're the only company addressing space, stationary, and transportation markets. We employ a total of 850 individuals, of which 350 are dedicated solely to fuel cell research and technology development. Over the years, our employees have amassed a patent portfolio of more than 550 U.S. patents.

UTC Fuel Cells produced its first fuel cell in 1961 for the space application. And since then, we've supplied fuel cells for every U.S. manned space mission. UTC Fuel Cells has also led the way with terrestrial fuel cell applications. We've sold 255 stationary 200-kilowatt units, known as the PC25, to customers in 25 states, 19 countries on five continents. Our installed base of PC25 has generated clean energy for over 6 million hours.

We're also a leader in the development of fuel cell systems for the transportation market. We count Nissan, Hyundai, and BMW among our transportation fuel cell partners. In addition, California's only hydrogen fuel cell transit bus in revenue service is operated by SunLine Transit and is powered by one of our fuel cell power plants.

Great progress has been made in fuel cell technology. For example, in the past 5 years, the life of a fuel cell stack has been extended from hundreds of hours to a thousand hours and, in recent lab tests, close to 10,000 hours. Costs have also come down dramatically from $600,000 a kilowatt for the space application to $4,500 a kilowatt for our PC25 stationary power plant. Our next-generation stationary product is targeted at an initial cost of around $2,000. And, of course, for automotive transportation uses, that has to go much, much lower, probably down to $50 a kilowatt or below. We've also achieved 50 percent reductions in size since 1977. The weight has decreased approximately the same amount. But we still have a long way to go.

The automotive application is the most challenging based on cost, durability, and performance requirements. The internal combustion engine has a 100-year head start and benefits also from huge volumes. Therefore, it will take longer for fuel cells to successfully compete in this market.

But the auto market also offers the largest payoff in terms of environmental benefits and our ability to reduce the Nation's dependence on foreign oil. We believe fuel cells will be deployed first in stationary devices, in fleet vehicles, such as transit buses, and only later in the personal auto market.

Transit buses are a strategic enabler on the path to autos powered by fuel cells. Hydrogen fueling stations can be made available, given the relatively small number of inner-city bus stations, and the power plant size and weight requirements are less demanding than those associated with automobiles.

We need to walk before we run, and gain experience in real-world operating conditions. Fleet vehicles represent a perfect candidate for this type of practical experience. As the industry gains experience in deploying fuel cells for stationary, inner-city buses, and fleet applications, these successes can pave the way for zero-emission fuel cell cars and serve as benchmarks to measure progress.

A team effort that involves original equipment manufacturers, power plant, component, and raw-material suppliers, energy companies, and governments will be required, with substantial sustained global investment by both public and private sectors.

Our recipe for successful fuel cell commercialization is included in my written statement. The top ingredients, however, are, one, development of a comprehensive, long-term national strategy with sustained national commitment and leadership; two, robust investment by the private and public sector focused on research, development, and demonstration programs for both fuel cells and hydrogen infrastructure, with an emphasis on renewable sources of hydrogen; three, financial incentives and government purchases; four, elimination of regulatory barriers; and, five, harmonized codes and standards that permit global involvement with open access to markets.

We've covered a lot of distance in the past few years, but we are engaged in a marathon, not a 100-yard dash. If the technical challenges are met, the private and public sector make robust investments, suppliers perform as predicted, consumer acceptance is won, and the necessary infrastructure develops as required, we anticipate the early adopter vehicle fleets will result in at least 10,000 fuel cell cars, trucks, and buses on the road by 2010, and a substantial amount of stationary fuel cell-generation capacity deployed. Mass production of fuel cell vehicles could then begin, starting in the 2012/2015 time frame.

UTC Fuel Cells believes that in order to meet the automotive challenge, a national strategy for fuel cell commercialization must focus on stationary and fleet vehicles to ensure our success in the automotive market and get us there sooner. At UTC Fuel Cells, we're proud of our past accomplishments, we're excited about meeting the challenges and opportunities that lie ahead so that the many benefits of fuel cells can be enjoyed not just by a lucky few, but on a global scale.

We look forward to working with you, Mr. Chairman and other Members of Congress, to ensure the fuel cell agenda noted above becomes a reality, and the full promise of fuel cell technology is realized.

Thank you, Mr. Chairman, for the opportunity to testify.

[The prepared statement of Mr. Preli follows:]

PREPARED STATEMENT OF FRANCIS R. PRELI, JR., VICE PRESIDENT–ENGINEERING, UNITED TECHNOLOGIES CORPORATION FUEL CELLS

Good afternoon, Mr. Chairman. My name is Frank Preli. I am Vice President of Engineering for UTC Fuel Cells (UTCFC), a business of UTC Power, which is a unit of United Technologies Corporation (UTC). UTC is based in Hartford, Connecticut, and provides a broad range of high technology products and support services to the building systems and aerospace industries. UTC Power is focused on the growing market for distributed energy generation to provide clean, efficient and reliable power. One of UTC Power's businesses is UTC Fuel Cells, a world leader in the production of fuel cells for commercial, space and transportation applications. I appreciate the opportunity to participate in today's hearing on "The Future of the Hydrogen Fuel Cell."

UTC Fuel Cells employs a total of 850 individuals and I lead a team of 350 engineers focused solely on fuel cell research and technology development. Over the years our employees have amassed an impressive list of more than 550 U.S. patents related to fuel cell technology.

UTC Fuel Cells produced its first fuel cell in 1961 for the space application and since then we've supplied all the fuel cells for every U.S. manned space mission. UTC Fuel Cells has also led the way with terrestrial fuel cell applications. We've sold 255 stationary 200-kilowatt size units known as the PC25 to customers in 25 states and 19 countries on five continents. Our installed base of PC25s has generated six million hours of clean energy.

We're also a leader in the development of fuel cell systems for the transportation market. We count Nissan, Hyundai and BMW among our transportation fuel cell partners. In addition, California's only hydrogen fuel cell transit bus in revenue service today is operated by SunLine Transit and is powered by one of our power plants.

In 1839 Sir William Grove discovered that combining hydrogen and oxygen in the presence of a catalyst could generate electricity. For many years the potential of fuel cells was untapped. Its use in the space program to generate electricity and provide drinking water for the astronauts represented its first practical application.

More recent technical advances plus the growing appreciation of the benefits of fuel cells including their clean, efficient, quiet operation and ability to reduce our dependence on foreign oil have captured the interest of not just the President of the United States, but also auto manufacturers, Fortune 500 companies, small business entrepreneurs, Wall Street, Congress, foreign governments and the general public.

The automotive application is the most daunting challenge and therefore it will take longer for fuel cells to successfully compete in this market. It's the most demanding in terms of cost, durability and performance. On the other hand, the auto market offers the largest payoff in terms of reducing toxic air emissions and greenhouse gas emissions related to global warming, achieving oil import independence and providing incentives for supplier investment due to the huge volume of cars produced each year.

The vision of an economy fueled by hydrogen generated from renewable energy sources is a revolutionary concept that will require evolutionary, incremental progress. We believe fuel cells will be deployed first in stationary devices and fleet vehicles such as transit buses and only later in the personal auto market. Transit buses are a strategic enabler on the pathway to autos powered by fuel cells. Hydrogen-fueling stations can be made available more readily given the relatively small number of inner city bus stations and the power plant size and weight requirements are less demanding than those associated with autos.

We need to walk before we run and gain experience in real world operating conditions. Fleet vehicles represent a perfect candidate for this type of practical experience since they offer an opportunity to enhance the range of operation for the vehicle, gain experience with heavy-duty cycles and train a core group of technicians.

As the industry gains experience in deploying fuel cells for stationary, inner city buses and fleet applications, these successes can pave the way for zero emission fuel cell cars and serve as benchmarks to measure progress towards the goals of the Administration's FreedomCAR and Fuel initiative. Similarly, we believe it is wise to continue the investments being made in electric drive train technology for hybrid cars and buses since fuel cell vehicles will incorporate this same technology and benefit from the technical advances and experience gained from these earlier vehicles.

Fuel cells must meet certain technical and performance criteria if they are going to be commercially viable and accepted in the marketplace. These metrics vary depending on the application, but automobiles represent the most daunting challenge. We believe consumers will demand that fuel cell power plants deliver cost, durability and performance equivalent to the internal combustion engine.

From a technical perspective, we've made tremendous strides in reducing the cost, size, and weight of fuel cells while increasing efficiency, and substantially improving durability. But we still have a long way to go.

For example, in the past five years we've seen extraordinary improvements in the life of the fuel cell stack, which is where the electricity is produced and represents the heart of the power plant. In 1998, proton exchange membrane (PEM) fuel cell stacks had a life of 100 hours. By 2001, our fuel cell stacks experienced a tenfold improvement to 1,000 hours and just recently UTC Fuel Cells demonstrated close to 10,000 hours of durability in laboratory tests.

Perhaps the most remarkable aspect of this significant progress is that it's been accomplished not in decades, but in a matter of years. Building on fuel cell experience from the 1960s, 70s and 80s, the use of sophisticated computer simulations, custom designed testing equipment and the extraordinary talent of dedicated and experienced engineers has made this possible. We're very optimistic that with continued investment in public private partnerships and focused demonstration programs to verify and validate our laboratory findings, we'll meet our durability target by 2010.

Fuel cell costs have also seen a dramatic decline. Fuel cells used in the space application cost $600,000 per kW; our 200 kW PC25 stationary unit introduced in 1992 costs $4,500 per kW; and our next generation stationary product that will be introduced next year is targeted at an initial cost of around $2,000 per kW. We've achieved similar dramatic reductions in size and weight that also have contributed to the reduction in costs. For example, fuel cell stack size has been reduced by 50 percent since 1997 and weight has decreased by approximately the same.

So while we've made substantial progress, we still have some challenges ahead if we are going to be competitive with the one hundred year old internal combustion engine technology that is produced in high volume. The cost improvements made to date have been achieved through a variety of strategies including improved use and performance of exotic materials, reduced number of parts, and enhanced manufacturing processes, but further development is required. Ultimately, we need to couple these technical successes with higher volumes to reduce unit costs.

At UTC Fuel Cells we're confident about meeting the technical challenges that lie ahead. Our forty years of experience in this business has taught us that there will be surprises (both good and bad) along the way and that the best way to learn is by doing. We're encouraged by progress to date, but we also know that the last percentage points of improvement are sometimes the most difficult to achieve and the most costly.

But there are other factors beyond our control that can influence the future of the hydrogen fuel cell. For example, we must ensure that similar progress is made in the development of the necessary hydrogen infrastructure including hydrogen production, storage and distribution. Codes and standards and safety procedures must be developed and uniformly adopted. Consumer confidence and acceptance must be won. The supplier base must be developed and must meet demanding specifications.

A team effort that involves original equipment manufacturers, component and raw material suppliers, energy companies and governments will be required with substantial, sustained global investment by public and private partners. Our recipe for successful fuel cell commercialization includes the following key ingredients:

1. Articulation of a comprehensive, long term national strategy that addresses stationary, portable and transportation applications;
2. Sustained national commitment and leadership;
3. Robust investment by the private and public sector;
4. Public private partnerships for research, development and demonstration programs for both fuel cells and hydrogen infrastructure with a focus on renewable sources of hydrogen;
5. Development and deployment of hydrogen production, storage and distribution infrastructure;
6. Financial incentives and government purchases;
7. Elimination of regulatory barriers;
8. Harmonized codes and standards in the U.S. and globally;
9. Global involvement with open access to markets; and
10. Education and outreach to ensure consumer acceptance.

We've covered a lot of distance in the past few years, but we are engaged in a marathon not a 100-yard dash. Fuel cell technology has experienced a long gestation period and will not reach its full maturity for some time. We anticipate the early adopter vehicle fleets will result in 10,000 fuel cell cars, trucks and buses on the road by 2010 and a substantial amount of stationary fuel cell generation capacity deployed.

This assumes that the technical challenges are met, the private and public sector make robust investments, suppliers perform as predicted, consumer acceptance is won and the necessary infrastructure develops as required. If all these efforts come together successfully, we can see mass production of fuel cell vehicles starting in the 2012–2015 timeframe. We envision a bright future for fuel cells, but recognize the challenges and uncertainties that we must address collectively.

My testimony today has focused on the progress made to date and the challenges facing the automotive market since this is both the most challenging and rewarding application. But UTC Fuel Cells believes that in order to meet the automotive challenge, a national strategy for fuel cell commercialization must focus on stationary and fleet vehicles to ensure our success in the automotive market and get us there sooner.

At UTC Fuel Cells we're proud of our past accomplishments and excited about meeting the challenges and opportunities that lie ahead so the many benefits of fuel cells can be enjoyed not just by a lucky few, but on a global scale. We look forward to working with you, Mr. Chairman and other Members of Congress, to ensure the fuel cell agenda noted above becomes a reality and the full promise of fuel cell technology is realized.

Thank you Mr. Chairman for the opportunity to testify.

Senator BROWNBACK. Thank you, and that is very encouraging. Ten thousand vehicles on the road by 2010. These fleet vehicles, that's what you project now.

Mr. PRELI. Obviously, a projection of how much will happen in the future is wrought with uncertainty. But if you look at extrapolations based upon the number of vehicles today, the number that some auto companies are projecting for 2005/2007, if we can make inroads in infrastructure, and if the technology comes home and the cost comes down, we think that's a reasonable assumption.

Senator BROWNBACK. That's a pretty short time frame to get there, too. I mean, a 7-year time frame to be able to do that.

Mr. PRELI. Right. I think the opportunity is here now. If you look at fuel cell technology development—it was invented in 1830. Not an awful lot happened. In the 1960s we did some work in space; in the 1970s and 1980s, in commercial. But I would say over the last 10 years, the level of interest and investment in this PEM technology, which is the potential technology for automotive, has vastly increased the number of minds and the amount of money being brought forward. And, really, the achievements over the last 5 years, maybe 10 years, are really stunning in terms of the evolution of fuel cells, since the 1830s.

Senator BROWNBACK. Is it safe to say, and I don't care who would want to respond to this—that as the scientific and engineering community looks to the future and wants to take the automobile out of the environmental equation, that this is, by far, the most promising technology?

Mr. MCCORMICK. I'll take that on for General Motors. Unambiguously, we believe that. And it's because we think that, in a sense, moving from petroleum to hydrogen gives us an awful lot of very substantial societal benefits. But moving to the electric driving allows us to do things with the automobile that we haven't been able to do before, as evidenced by our Hy-Wire concept, where we now can package cars and design them in ways that give better style and better utility than the conventional designs we have that have to design around the hard mechanical interfaces between the engine, transmission, and wheels. And so, in a sense, this idea of having customers that want to buy, what we sell is performance, transportation, for sure, utility, which has something to do with how the vehicle is designed. And most people buy vehicles, to a large degree, based on style and fun, as well. So you've got to put all that together. And these new concepts allow us to design vehicles that we think people absolutely want to buy. So, from our viewpoint, it's a win all the way around.

Dr. FRIEDMAN. If I might add to that. I think this is one of the areas that's really encouraging, because the automotive industry and, generally, the environmental community and scientific communities agree that fuel cells hold amazing long-term promise. I do have to underscore, though, that it is promise. Hydrogen is only as clean as how it is made. So if it is made from coal, if it is made from other dirty resources, we will definitely not be taking vehicles out of the equation. So it's very important that as we look forward to developing fuel cell vehicles, that development also happen for the energy resources to make sure that the hydrogen can be as clean as possible.

It's also important that we develop a lot of other technologies. A lot of the conventional technologies and a lot of the hydro technologies will actually feed into fuel cell vehicles. For example, the electric motors in hybrid vehicles and the aerodynamic improvements or better rolling-resistance tires, in conventional vehicles all are very important to ensure that fuel cell vehicle costs can come down and that their efficiency can be maximized.

So there's a real synergy between those technologies that's important to take advantage of.

Senator BROWNBACK. But, Dr. Friedman, I want to make sure I understand. You believe, as well, representing the Union of Concerned Scientists, that hydrogen technology represents the most promising aspect of taking the automobile out of the environmental impact equation?

Dr. FRIEDMAN. As long as hydrogen technology is linked to renewable fuels, definitely.

Senator BROWNBACK. Mr. Preli, do you agree with that statement, too, that hydrogen is the key opportunity that we have here in taking the automobile out of the environmental equation?

Mr. PRELI. Yes, I think we agree with that, and I think our concern is really when—Sooner or later, fossil fuel reserves dwindle down, you have to make a switch. How quickly do you move toward that goal?

Senator BROWNBACK. Mr. Friedman, I want to go to a statement that you made that hydrogen is an energy carrier, not a "energy fuel." And I see your difference, and I agree with that. What sources—and perhaps you can state even generally from the environmental community—should we be deriving hydrogen from?

Dr. FRIEDMAN. Well, certainly that's a near-term and a long-term question. In the near-term, I think natural gas is likely the most promising source of hydrogen. If you look at this projection for basically getting 50 percent of the new vehicles as fuel cell vehicles by 2030, then kind of look back at 2020, where we're expecting maybe 10 percent of the new vehicles would be fuel cell vehicles, the hydrogen demand is on the order of one quad of energy. To make that from natural gas, that's about two quads of energy, which is less than 10 percent of the projected natural gas demand in that time frame. So as a transition fuel, natural gas makes a lot of sense, specifically because you can put a natural gas reformer at the fueling station. So instead of necessarily having to build up the infrastructure in the short term to pipe hydrogen to fueling stations, you have a reformer——

Senator BROWNBACK. You just pipe natural gas to the station.

Dr. FRIEDMAN. Exactly, and then you crack the fuel there.

Senator BROWNBACK. Is it that cheap to be able to make that transfer technology where you crack it right at the station?

Dr. FRIEDMAN. Well, in terms of technology, that technology is actually what UTC Fuel Cells is using for their stationary technology for the PC250s or PC25—sorry if I'm saying them wrong. Certainly, it's still more expensive than gasoline, and it will take time to get that down. It will also probably take tax credits, infrastructure tax credits and fuel tax credits such as are being looked at in the CLEAR Act in order to help, in the short term, bring down those costs.

In the long term, because fuel cell vehicles can be on the order of two to three times more efficient than the cars we have today. The price for the fuel can be higher than gasoline, but because the vehicle is so much more efficient, the actual on-the-road price can be quite similar.

Now, in the long term, though, we can't rely on natural gas. Obviously, there are still carbon emissions associated with natural gas, and there are some upstream emissions and air pollutants associated with producing natural gas. Ultimately, we do need to move to electrolysis-type technologies based off of wind and solar energy, as well as using biomass to gasify and produce hydrogen fuel.

Senator BROWNBACK. Gentlemen, do either of you have any comments to make about his analysis of the sourcing of the hydrogen?

Mr. MCCORMICK. Maybe we see it somewhat differently. And if you use the analogy of electricity, which, in the future, we envision, there are two energy carriers, one being electricity, one being hydrogen. The earlier we begin to get the infrastructure in, get the vehicles out there, and get the fueling infrastructure in, then we have the opportunity over time to balance environmental policies, economics, balance-of-trade kind of issues and other real-world things that we have to balance in order to fundamentally come up with what's our national policy around these issues. And so a bit like electricity, once the grid's in, then you can decide incrementally how do I want to move my base production of electricity, how do I want to deal with the environmental issues. And so the quicker we begin to get the vehicles out there and get the infrastructure in, the better we are in terms of developing that path to renewables that we've just talked about.

Senator BROWNBACK. You know, it's exciting to hear it being talked about here, as it's frequently—as long as I've been around, there's been tension between the automobile community and the environmental community, and I don't sense that same level of tension here. There's a, it seems to me, a coming together of interests, which is a delight to see.

Mr. McCormick, congratulations on the historic announcement this morning that GM did with Dow Chemical, provide fuel cells with, as I understand it, generating capacity of 35 megawatts at Dow's Freeport, Texas plant. Could you speak to some of the business advantages that both companies experienced? Because you noted this was a straight business-to-business arrangement that both saw advantages from.

Mr. McCORMICK. Right. And, if I may, I'd like to generalize some business-to-business opportunities beyond this.

First of all, it's in the nature of the chemical industry that quite often one of the things they produce is hydrogen. And they have——

Senator BROWNBACK. What do we do with that now?

Mr. McCORMICK. Pardon?

Senator BROWNBACK. What's done with that now?

Mr. McCORMICK. Well, what they do with it now is one of two or three things. They'll sell it into the merchant hydrogen business, they'll clean it and sell it. Second of all, they'll combust it to create some heat or to create—put it into a turbine or something and generate some additional power. Or, thirdly, in some cases it's vented. And, therefore, that hydrogen is there as an economic commodity. And if we then put it through a fuel cell and take advantage of the efficiency of the fuel cell, we allow Dow, then, onsite to generate electricity to help run their own facility. So what they're doing is they're taking the basically free hydrogen, running it through a fuel cell and playing that off against the need to buy electricity off of the grid. And in so doing, you notice that also now that they're going to have some real big environmental benefits, because they are not driving coal-fired power plants or other power plants to generate that electricity for their facility. So it has many, many wins, both societal and business-wise. But, fundamentally, that's the win for them.

The win for us is that you don't go from the laboratory to generating 5- to 10 million vehicles a year all in one step. And so what we need to do is take that automotive technology and begin to build 1,000, then 10,000, then 100,000. Because not only is it important what we do in General Motors, but we have an entire supply base to transition. And our suppliers that make sensors or membranes or catalysts or gaskets or whatever have to go through that learning with us. And so it's very important that we bring this out of the laboratory and start getting real experience with it.

So this was a pure business-to-business opportunity. At the cost of fuel cell as we have them, or will have them during the next couple of years, it turns out it's a profitable venture for both of us. Pure business.

Now, I would comment that——

Senator BROWNBACK. Well, I hope when you open that up, you'll have a public announcement and reception for people so that they can look at that. That's an exciting development.

Mr. McCORMICK. One of the other things that I think is implied in the discussion of what we call "forecourt manufacturing" of hydrogen in the filling station is that the technologies we're talking about, fuel cells, work well in small sizes and in large sizes. The fuel processors are nicely scalable. We built a car which had a small fuel processor on it. The people at UTC build small fuel processors, large fuel processors. Electrolyzers also work well when they're small or well when they're large.

Consequently, the notion that you have to do everything centralized in some big massive capital-intensive way is not appropriate in this environment. So the idea that we can start to put in small fuel processors, small electrolyzers, as there's a few cars out there and the demand's not large, and later put in larger facilities as that demand grows, gives us an opportunity to, sort of, manage that transition. And that's a key difference, in terms of how this transition can happen.

It also means that whenever there's an economic inefficiency, because we've got lots of sources of energy and lots of ways to convert it to hydrogen, if one of the economic factors is out of whack, somebody can arbitrage it. That is, somebody can make hydrogen from some other source, and so you start to get free-market competition here, which, at the end of the day, is going to stabilize markets and drive good competitiveness.

So the key is for us to get the fuel cell vehicles out there and begin to get that infrastructure started.

Senator BROWNBACK. Now, you stated that a typical fuel cell vehicle produces 50 to 75 kilowatts of electrical power, and I think you also noted that not all of that's going to be needed in the vehicle and that in turn could be used to generate electricity?

Mr. MCCORMICK. Well——

Senator BROWNBACK. I mean, you're not going to plug your car into the house and start running the house, are you?

Mr. MCCORMICK. Well, in fact, look at that. We had—well, think about the tornados in your state and others recently where there's disruption of electric power. A couple of weeks ago in Detroit, we had an ice storm that caused 175,000 people to be without power. And so right off the bat, the notion of a, let me say, "reconfigurable electric grid" becomes very, very pragmatic. Now the electric cars can help power the grid and help deal with emergencies, homeland security, those kind of things.

Finally, because of the way that—I've got to be very careful how I say this, because I'm not an expert on it—but, quite often, utility rates are set by the peak that you use over some period: a year, a month, or whatever. The ability to plug your car in and just occasionally peak-shave, particularly during the summers when your air conditioner is driving a lot of the power, could change the utility rates a lot. Remember that the brownouts in California and other places are not due to base-load generation; they're due to peak. And so what you'd like to be able to do, as a society, is take that peak offline so that you don't have to build all that base load. So the vehicles, again, could play a key role and be economically a very, very pragmatic solution to that.

Senator BROWNBACK. Mr. Preli, would you comment about that?

Mr. PRELI. Well, I think if you look at the automobiles, particularly in the United States, it's a largely underutilized capability. Automobiles are operated about 10 percent of the time, and the other 90 percent of the time they're sitting in a parking lot or a garage. So if you were able to tap that, then all of the effort that goes into building an automobile could be put to much better use, in that you could use it for generation of electricity at an industrial site, at a home, or anywhere else that you need electricity. Really, the home load would be an automobile more or less idling. Its idle capability is more than enough to power a home. And maybe you would even form micro-grids at an industrial site to tap that power if you had hydrogen available.

Senator BROWNBACK. So, you would see the possibility that people drive into work, when they get there, they would plug their car in to generate electricity at the work site?

Mr. PRELI. It's certainly possible, but we would have to change the design of the power plant for the automobile a little bit, because right now, let's say an automobile lasts for 10 years, which is 87,000 hours, of which maybe you'll use it for 8,700 hours, perhaps. If you're going to use it more, then the power plants would have to be designed to live more like a stationary power plant. For example, the PC25 power plant we currently market has a minimum life of 40,000 hours, and we have units that have run to 60,000 hours. So if you're going to use these as more of a stationary power-generation capability, you would have to improve upon the design life of the power plant. But that's certainly doable, both GM and ourselves are looking at the stationary market as an early market for these types of fuel cell power plants.

Senator BROWNBACK. What are the top two or three policy issues that we have to get right to press this technology forward?

Dr. Friedman?

Dr. FRIEDMAN. I think there is—the top policies in one is—sadly, we don't have a fuel supplier here today, but supplying the fuel and making sure the fuel gets out there is probably one of the most important hurdles; and that's much less of a technical hurdle, it's much less of an engineering hurdle, and it's more of a question of sustained commitment from the Government to provide certainty for fuel companies that they're going to have a market.

The auto companies have been investing billions of dollars over the last several years to get fuel cell vehicles developed, and they've been really making a lot of progress.

The fuel companies have not been really been making as large an investment, because they're waiting for a lot of the vehicles to be out there. But the vehicles aren't going to be out there unless the fuel is out there, and you get into this chicken-and-egg problem, which is where I think the Government can play a very significant role in helping to assure the fuel companies that there is going to be a market, to help mitigate their risk and their financial risk.

Part of the way to do that is by providing tax credits for putting in infrastructure, tax credits for actually selling the fuel, especially in the early years so that you can bring down the initial costs of hydrogen.

I think, second, it is very important to deal with the storage issue, as we heard earlier today, but I don't see that as as major of a stumbling block. We've seen studies by Ford Motor Company that show that, with really good packaging, they can get over a 300-mile range with 5,000 psi tanks. But storage is an important issue.

And I think, also, education is important. It's very important that we train the next generation of engineers so that they are ready to deal with fuel cells and fuel cell technology. It requires a much more interdisciplinary engineer than your typical mechanical, electrical, or chemical engineer.

Finally, I would say that one of the important things we need to do to make ourselves ready for fuel cell vehicles is to do something about oil consumption as soon as possible, investing in other conventional technologies so that the problem doesn't continue to grow and so that the urgency for fuel cell vehicles maybe isn't as large and we can wait and we can afford to wait until the technology is ready.

Senator BROWNBACK. Mr. McCormick?

Mr. MCCORMICK. Well, I have four. First of all, when people talk about the cost of hydrogen, a lot of that cost is in the capitalization of the hydrogen generation hardware; it's not necessarily in the hydrogen itself or the raw fuel that makes the hydrogen. So as we go forward, policies that enable people to put in the capitalization and get it amortized or get it written off quickly; or maybe, in the extreme cases, in the railroads when they were put in the United States west of the Mississippi, they were highly subsidized by the Government, because there wasn't enough population to support having profit-making railroads there. So there's a number of ways that the Government can think about dealing with what I'll call the "capital issue." I don't want people to be misled, to think that the cost of hydrogen is purely a technical issue. In fact, to a minor degree, it's a technical issue. It's primarily a financial issue.

The second one is codes and standards, and it comes in two forms. Codes and standards as it relates to putting in the hydrogen fueling stations, in particular. When we did the electrical vehicles in California, we found that we had to go to every municipality, every—people that handle jaws of life, everybody that could license anything and try and convince them to put the electric chargers in. It means that nationally we have to really start harmonizing codes and standards work across the national Government.

Number two, if we're going to have this—around codes and standards, if we're going to have this merging of hydrogen and electricity and the ability to switch back and forth between the two or use the vehicles to power the grid or have distributed generation, it means that we need codes and standards for connection onto the electrical grid. Right now, public utility commissions in each location have sway over how that happens, and so consequently it's a very difficult proposition to really move distributed electrical generation into the market, except in select places.

Number three, this sounds strange, but I think this is a long-term proposition. We start, if we're going to make a change that happens in 30 years or even 50 years, the first 10 years, this next 10 years, are absolutely pivotal to us, and so what we need are policies that don't change every year or two. They've got to be policies that envision continuity for periods of 20 and 25 years if you want this kind of a transition to happen.

As we talk to fleet users, one of the problems with some of the earlier initiatives is that fleet users will begin to get ready to take advantage of the tax credits, only to find out the tax credits have gone away because they're 4 years out, and by the time people get the planning, get the capital, get ready to do it, all of a sudden the incentive to do it is gone. So I think we need to be looking at 20-year kinds of policies and make them consistent.

And then, lastly, we're beginning on a journey. And, in a sense, as one college student told me recently, we're moving away from the theme of fire to the theme of electrochemistry. And when we look at that, the fuel cells that we're putting out in the next 10 years are going to be absolutely antiquated and obsolete by the technology that's possible. And so, consequently, I think that we need now to be energizing some of the best scientists in the country, places like National Science Foundation, NIST, many other of the research agencies and people who could take on very aggressive kinds of things.

We're going to drive that cost curve, our technical suppliers and the supply community are going to do that, but I look to the day when we don't even think about using precious-metal catalysts, maybe organometallic catalysts and things that are much more aggressive. And I think now is the time, as we get those first vehicles out there and we start moving, that there's a whole body of new technologies for us to implement in the 2010 to 2020 time frame.

Again, I think we should be looking at the short term to implement, but I'd also like to see some really good research to get some of those Nobel Prize winners to look beyond what we're doing. And those would be the four things I would have in mind.

Senator BROWNBACK. Mr. Preli?

Mr. PRELI. Perhaps this is redundant. It may be surprising that we all agree. I'll run down my list, maybe for reinforcement.

I think we need to lead in the development of technology, both short-term technologies, like improving durability and lowering cost, but, in particular, we need to lead in advanced concepts. We're at the Model-T stage in terms of fuel cell development, and there's many, many more advancements to come, and I think the U.S. needs to lead in that regard.

I think we need to provide a forum for demonstrating these technologies, make things easier to demonstrate, in stationary, bus and fleets, and auto.

I think we need to lead in the development of an infrastructure, because one fear I have is that the technology is moving very, very rapidly, maybe more rapidly than some of us originally anticipated, but the technology is not very useful without an infrastructure to fuel.

And then, finally, to continue to spur the market through incentive programs.

Senator BROWNBACK. That's very good. Very good thoughts and comments.

Gentlemen, I very much appreciate your testimony, your enthusiasm, your unity on an important, important topic for us. This was an exciting forward-looking hearing.

I would like to join Mr. McCormick in inviting people here to go view—I hope to drive it. My license is good, I have insurance to be able to drive it. Where is the vehicle located, Mr. McCormick?

Voice: Back by the Russell Building, out the back door, on the corner of C Street and First.

Senator BROWNBACK. Oh, very good.

Mr. MCCORMICK. If you follow that gentleman right there, he'll——

Senator BROWNBACK. So if we follow the gentleman over here, then people can look and see, possibly drive it.

It's an exciting issue, and I hope you'll continue to work with us.

Thank you all for coming. The hearing is adjourned.

[Whereupon, at 4:24 p.m., the hearing was adjourned.]

A P P E N D I X

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO FRANCIS R. PRELI, JR.

Questions 1. What does one do with the water byproduct? Store it on board, release it to the atmosphere/street?

Answer. Excess water is released to the atmosphere as water vapor and as liquid water. Internal combustion engines also release large amounts of water, but because they operate at higher temperatures than Proton Exchange Membrane fuel cells, the water is usually in the gaseous form. Sometimes, particularly when the engine is cold, you can see water dripping from the exhaust pipes. With fuel cells, on cold days, some heating of the water may be needed to make sure that a lot of liquid water does not drip out.

Questions 1a. And do we have enough clean water to make this thing work, or do we need to be looking at large water purification plants to accompany hydrogen plants?

Answer. Water is formed as a by-product of the hydrogen and oxygen reaction and so large amounts of pure water do not need to be supplied to the fuel cell engine. About 3–10 liters of water may be required at initial start-up, but the fuel cell uses its own water to make up any losses.

Questions 2. Where does the oxygen come from? (A fuel cell combines oxygen and hydrogen to make water and heat/electricity. We're focusing on making hydrogen. Is the oxygen pulled out of the air, or is it stored onboard like the hydrogen?)

Answer. The oxygen comes from the air. The fuel cell operates better on pure oxygen (as in our fuel cells for the space shuttle), but operates very well using oxygen from air. The improved performance from pure oxygen does not outweigh the cost, storage and safety issues encountered with pure oxygen.

Questions 3. How quickly can you see hydrogen powered vehicles making a significant impact? (e.g., 20 percent of the market by 2020, 2030 . . . ?)

Answer. As indicated in our written testimony, the answer to this question depends on many variables. Assuming that the technical challenges are met, the private and public sector make robust investments, suppliers perform as predicted, consumer acceptance is won and the necessary infrastructure develops as required, we can see mass production of fuel cell vehicles starting in the 2012–2015 timeframe. This scenario also requires that we are successful in the deployment of stationary and fleet vehicles such as transit buses as important stepping-stones to the deployment of fuel cell automobiles.

UTC Fuel Cells is working diligently with its auto and fleet customers to increase the durability and reduce the cost and size of fuel cell power plants so they can compete with the internal combustion engine. We estimate that size/power density is within 30 percent of the target required for wide spread auto usage of fuel cells and progress on durability is very encouraging. Cost, however, remains a significant challenge since the internal combustion engine enjoys a one hundred year head start and benefits from high volume production.

The convergence of the required size and cost of a fuel cell system for the automotive market with all the performance criteria demanded by consumers is very dependent on continued R&D investment from the auto sector and fuel cell component and raw material suppliers. Presuming that investment continues to accelerate, we could foresee a truly competitive fuel cell system in the 2015 time frame. Of course there will be niche markets as much as five years earlier than that.

The milestones to watch for are continued investment from the major automotive companies in fuel cell R&D, particularly when those investments are made in the absence of legislative initiatives. When that happens, it will be a signal that the automakers believe they will compete head-to-head within the next ten years on the efficacy of their respective fuel cell technologies. If those R&D investments decline when legislative initiatives lose momentum, it will be a signal that fuel cell market entry will be delayed. Additionally, if there are significant legislative initiatives or a major upward swing in the cost of petroleum products, the introduction of fuel cells to the auto market place could be accelerated by as much as three to five years.

Questions 4. Will hydrogen be able to compete in the absence of policy measures (e.g., carbon credits), considering that it is more costly with the present carbon-based fuel prices?

Answer. The conversion to hydrogen will be costly. The U.S. must use some form of incentives to stimulate the conversion process and must lead the development of infrastructure.

Questions 5. Should the federal government be picking hydrogen and fuel cell vehicle technologies over other technologies, such as hybrid vehicles and lean burn engines?

Answer. Hybrids are an important bridging technology for fuel cells because they will solve the electric drive issues and will help reduce the costs of such systems. High-volume manufacturing of hybrid vehicles will make the eventual conversion to hydrogen fuel cells easier.

Questions 6. Would the designation of a target deadline for commercialization of fuel cell vehicles help focus the program and make better use of funding resources? Alternately, would such a deadline force manufacturers to abandon other promising technologies or create an unfair burden on the industry?

Answer. A plan that includes aggressive milestones is appropriate. These milestones should include both technology and product goals so progress can be measured on an annual basis. We believe too much emphasis is being placed on 2015 commercialization goals without looking carefully at the intermediate steps.

Questions 7. Should the government focus on long-term research or should it focus on technologies closer to commercialization, or both?

Answer. The government should develop and implement both short and long term strategies. In the near term, the deployment of stationary fuel cells needs the support of the government through tax credits and as a purchaser of fuel cell products. In the mid term, fuel cell busses are the best way to begin deploying the technology for transportation because the technical requirements are not as demanding as for automobiles and hydrogen infrastructure can be developed. A near and long term R&D program is also needed to improve durability, operability and to lower the cost. But a single focus on long-term R&D will discourage near-term applications and reduce the ability to acquire design and usage feedback for today's state of the art technology.

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