DEPARTMENT OF ENERGY'S FREEDOMCAR: HURDLES, BENCHMARKS FOR PROGRESS, AND ROLE IN ENERGY POLICY

HEARING

BEFORE THE

SUBCOMMITTEE ON
OVERSIGHT AND INVESTIGATIONS

OF THE

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THURSDAY, JUNE 6, 2002,

HOUSE OF REPRESENTATIVES,
COMMITTEE ON ENERGY AND COMMERCE,
SUBCOMMITTEE ON OVERSIGHT AND INVESTIGATIONS,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:30 a.m., in room 2123, Rayburn House Office Building, Hon. James C. Greenwood (chairman) presiding.

Members present: Representatives Greenwood, Stearns, Gillmor, Bass, Fletcher, Deutsch, and Dingell (ex officio).

Staff present: Peter Spencer, majority professional staff member; Joe Greenman, legislative assistant; Yong Choe, legislative clerk; Jonathan J. Cordone, minority counsel; and Bruce Gwinn, minority professional staff member.

Mr. GREENWOOD. Good morning. The meeting will come to order. Today we'll be examining a far-reaching and quite bold automotive research initiative that has been launched by the Department of Energy and the big three automakers.

The FreedomCAR program, a public-private research and development initiative, presents a vision of a day when automobiles will not be only pollution free, but no longer dependent on petroleum. This is a bold vision indeed.

The focus of this initiative is for the long term, of course, which may have merit for setting priorities, but it also raises some basic issues I hope we can explore in depth today. Some of these issues involve assuring that we will be able to assess, as the program moves forward, whether taxpayer money is well spent. Some issues also involve placing this program in the broader context of our energy policy, an important area of the full committee's jurisdiction, and fully appreciating the challenges the program will face.

Some of you may remember the large ad campaign a couple of months ago for the new model lineup from Nissan's Infiniti division. The flashy ads displayed futuristic vehicles, the kind we used to read about in Popular Science, with the catchy question, "where are the cars we were promised?"

We know now those so-called future cars promised to be right around the corner were never delivered. The ads struck me, because they pointed to something I think can affect our thinking about future technology. We can get carried away with our imagination, only to be disappointed by reality. This is not to say that we shouldn't have bold visions that go beyond what we are presently capable of achieving. Innovation would wither away otherwise. But it should serve to remind us as we go forward with spending from limited resources to seek policy goals that are important for our Nation that we must maintain some perspective and be willing to say no when a vision goes off track.

The two panels from which we will hear this morning should help us make sure that we stay on track with this program so that we can be confident it is a beneficial pursuit for our Nation's energy policy goals. The panelists should help us check whether we will be able to assess as time goes on that the program fits with policy goals, that it will make a positive impact on our efforts to reduce our oil dependence and cut pollution, or whether adjustments are necessary.

At the outset, there are some key questions we need to consider about the respective roles in the program of the Department of Energy and the U.S. Council for Automotive Research, which represents the auto makers.

For example, there are some threshold questions about the structure of the program. What is the role of industry in this partnership? How is the money spent? Where does it go? There are questions about the balance of the technology portfolio currently being pursued by FreedomCAR. Has the shift in focus to a fuel cell, hydrogen future diminished the pressure to get the intermediate gains in automobile efficiency we've already been researching and spending more than a billion dollars on these past 8 years?

As our General Accounting Office witness will point out in his testimony, reviews of past R&D efforts by the Federal Government reveal that, surprise, surprise, some of these efforts have come up short due to lack of focus, absence of measurable goals and benchmarks, or failure to consider actual marketplace potential of the research. Some efforts have produced positive results, so we have some experience here that offers up lessons we should consider as we examine FreedomCAR.

It is essential that we examine this program in the context of our broader energy policy. We must consider how the pieces, the technology portfolio, the benchmarks and goals fit together to make an actual difference in how we use energy and in what we emit into the air. When all is said and spent, this initiative should enable the production of something that consumers and businesses will want to purchase and use. Is FreedomCAR structured to help launch products and innovation into the marketplace?

Is the strategy contemplated by the Department of Energy sufficient to prevent advances from gathering dust on a lab shelf? Panelists today will help us put FreedomCAR's goals and its connection to a hydrogen future in proper perspective. I look forward to discussion about the requirements for infrastructure, the demands on fuel supply, the cost barriers and challenges. I look forward to learning about what Congress may have to consider to help address these issues. I'm not sure that all that will be involved or how long this vision will take to be realized has been fully appreciated by the public.

Moreover, I'm not sure the questions are settled about the current course of FreedomCAR. We will hear today about other aspects of research and development concerning hydrogen infrastructure. For example, that might need more immediate attention if the hydrogen vision is to overcome the chicken-and-egg problem. Unlike conventionally fueled vehicles, after all, you can't really convince people to leap to fuel cell cars unless they can drive them far and wide without worry about filling up.

Finally, as we step back to view the program in a broad context, we should also not lose sight of its potential for positive side effects. There is something to be said about long-range focus. Properly sighted, it can generate research outcomes we cannot even contemplate as it fosters innovation.

So I'd like to kick off this hearing on that upbeat note, but without forgetting that we should not let our imaginations get too far ahead of us when we're spending the taxpayers' money.

[The prepared statement of Hon. James C. Greenwood follows:]

PREPARED STATEMENT OF HON. JAMES C. GREENWOOD, CHAIRMAN, SUBCOMMITTEE ON OVERSIGHT AND INVESTIGATIONS

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Now, this is not to say that we shouldn't have bold visions, visions that go beyond what we're presently capable of achieving. Innovation would wither away otherwise. But it should serve to remind us, as we go forward with spending from limited resources to seek policy goals that are important for our Nation, that we must maintain some perspective, and be willing to say no when a vision goes off track.

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Mr. GREENWOOD. The Chair recognizes the ranking member, Mr. Deutsch.

Mr. DEUTSCH. Thank you, Mr. Chairman. Again, I appreciate this hearing. I don't think that there is a more important domestic policy issue than what this program is about. The potential in terms of fuel cells would have a dramatic effect on our national security, on our macroeconomy, and so it clearly is a very, very high priority in terms of the goals of this country, and I look forward to the testimony and working with the committee and the committee staff in trying to make this program as successful as possible. Thank you.

Mr. GREENWOOD. The Chair thanks the gentleman and recognizes the gentleman—the other gentleman from Florida—Mr. Stearns, for an opening statement.

Mr. STEARNS. Thank you, Mr. Chairman, and I thank you for having this hearing. Over the past year and a half, much of the energy policy debate has centered around CAFE standards. Obviously as summer approaches, more Americans are taking more vacations. The demand and subsequently the price of gasoline is increasing. Add to that the tensions in the Middle East, and we are again looking at possibly a higher set of gasoline prices this summer.

As America searches for ways to become more self-sufficient in energy consumption, we're also looking for ways to reduce consumption. So I believe today's hearing shed light on the problem talking about perhaps not a new approach, but an improvement over an older approach to fuel efficiency. As many of you know, nearly 9 years ago, President Clinton announced a new government and industry program called the Partnership for New Generation of Vehicles. The goal was to eventually produce an environmentally friendly vehicle that would achieve greater fuel economy without sacrificing performance, affordability and safety. These are the same influential factors within the CAFE standards debate. As many are concerned that arbitrarily raising CAFE standards would hurt these same areas.

The new program brought together the resources and expertise of both the private sector and the Federal Government. The research centered around reducing U.S. oil consumption by developing new technologies, such as hybrid electric fuel cells and lightweight materials. At the beginning of this year, the Bush administration decided to expand the research and development of fuel cells within a new initiative called FreedomCAR. This expands upon the old partnership initiative, while narrowing the focus. Fuel cells offer the most promising opportunity, especially in terms of domestic production. In addition, the new initiative focuses on expanding the use of new technologies across a wider spectrum of car manufacturing design so as to make such technologies more marketable.

And this makes business sense. In light of President Bush's energy policy and the desire for all of us to wean ourselves off the nearly 60 percent reliance on foreign fuel imports, the FreedomCAR initiative is a proper step in focusing these research efforts to a more and what we hope to be achievable goal.

As a member representing a State that imports nearly 100 percent of its fuel needs in Florida, I support common sense approaches to fuel efficiency and the increased use of new technologies. So, again, Mr. Chairman, I thank you for this hearing. Look forward to our witnesses.

Mr. GREENWOOD. The Chair thanks the gentleman.

[Additional statements submitted for the record follow:]

PREPARED STATEMENT OF HON. PAUL E. GILLMOR, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF OHIO

Mr. Chairman, given the recent focus on formulating our nation's energy policy, I am grateful for this opportunity to address the status of the DOE's new FreedomCAR program. In particular, I am anxious to hear about the progress of fuel cell technology and FreedomCAR since its announcement last January.

Like many of the Members here, I support conservation efforts, while at the same time, enhancing the use of renewable energy resources, improving energy efficiencies, and increasing domestic energy supplies to decrease America's dependency on foreign oil. At the onset, I believe this program is a step in the right direction to achieve this goal.

However, with a technology of chemically generating electricity from hydrogen, one that is not market-ready in our nation's automotive industry, I feel it is important to continue to improve upon and give attention to current technologies such as hybrids.

Furthermore, as we delve into this issue, I am hopeful that this program will produce long-term goals that motivate researchers, inspire the public, and provide the appropriate avenues to measure progress.

Again, I thank the Chairman and yield back my time.

PREPARED STATEMENT OF HON. W.J. "BILLY" TAUZIN, CHAIRMAN, COMMITTEE ON ENERGY AND COMMERCE

Thank you Chairman Greenwood. And, let me also thank you for putting together what promises to be a very interesting hearing this morning on the Department of Energy's FreedomCAR partnership.

Several policies we pursue on this Committee aim, in one way or another, to encourage innovation and technological advancement and to assist efforts to deploy workable innovations into the marketplace. Whether it is pharmaceuticals, telecommunications, the Internet, or, of course, energy, the bulk of this innovation comes from private sector initiatives.

Clearly, the federal government can and does aid in this process. It pursues its own research and development, which has spin offs into the market—think of the Intemet's development, for example. And it can implement policies that encourage (or at least don't stifle) the innovative and technological pursuits of those in the private sphere. The federal government also can serve as an incubator of sorts, or can assist through demonstration projects and the like, where there is promise but not enough incentive for individual companies to pursue.

Or, in the case of the program at hand, federal R&D can work in partnership with the private sector—and appropriately so, if it is properly structured.

However, I think there's a delicate balancing act, which we in Congress must monitor very carefully. We have a responsibility, as you indicated Mr. Chairman, to make sure taxpayer dollars are spent wisely on initiatives that are in the public interest—and that hold some promise of producing results. And as Members of this Committee, with its broad jurisdiction, know quite well, we also have limited resources, but a seemingly unlimited number of vexing problems we'd like to address.

I look forward to learning from the witnesses about the structure of this program, and the measures in place, or that will be put into place, that will assist Members as well as the agency and automaker planners themselves to track the progress of FreedomCAR, and to correct its course, if necessary.

I also look forward to hearing about the prospects of this program in our dynamic marketplace, and the ongoing innovations and changes that occur in the transportation sector.

It's been encouraging to see advances such as hybrid vehicles coming into the market, and to see demonstrations of other advanced engine technology on the verge of market introduction. When we consider the goals of this program, it's important to look at them against the backdrop of the marketplace, rather than just a blackboard.

It's also important to look at the goals in the context of our nation's energy policy, which, as it happens, is one of the Energy and Commerce Committee's front-burner issues at the moment.

I look forward to learning about the broader, but related, goals of a leap to a hydrogen economy. I'd like to hear more about how this will effect our energy usage, how it will effect innovation and the future of transportation, and our economy. These are big questions. I'm pleased we're taking a stab at them today.

I thank the witnesses for taking the time to come and discuss these important issues with us, and I yield back, the remainder of my time.

PREPARED STATEMENT OF HON. DIANA DEGETTE, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF COLORADO

Mr. Chairman, thank you for holding this hearing today and I thank our witnesses for being here as well. FreedomCAR does have a nice ring to it. I hope that the program's goals go deeper than that, though. I'd like to see substantial changes in the vehicles we drive.

As a member of the Renewable Energy and Energy Efficiency Caucus, it probably will not surprise anyone here that I am very interested in today's discussion. I strongly believe that we have to think creatively to solve our current energy needs and look toward solving the energy needs of tomorrow.

I have been in Congress for three terms. But I have a lot of friends and colleagues who have been here for much longer. I won't name any names. When we get to talking about these projects to develop cars and trucks that are more fuel efficient, they tell me how they have been talking about how the fuel cell vehicle is just around the corner. Those conversations, I'm afraid to say, have taken place for the last three decades. And we are still having the same conversations.

I don't think I'm alone in realizing how important it is to develop new technologies that will help our country to be less reliant on oil. Of course our current oil dependence is largely driven by our car culture. Major assertions to the contrary, we have not made great strides in implementing technologies that substantially improve gas mileage. Instead, the recent trends toward larger and larger vehicles have only increased this dependence.

I like the sound of Secretary Abraham's assertions that this project aims to "leapfrog the status quo" and pursue "dramatic environmental benefits." I look forward to hearing how the goals of this program differ from earlier federal efforts and how they are more achievable. We do not want to re-invent the wheel here. By that, I am saying that I think we need to continue to build on the research that has already taken place.

I want to talk about how we aim to implement any new technologies we develop. How do we build on past research to develop the next generation of vehicles that will actually wean us from our dependence? How do we safely transport and store hydrogen?

I think this is also an excellent opportunity to further explore some interim solutions. I am glad that the Department of Energy has decided that we are heading to a day when we all drive clean, fuel-efficient, hydrogen-powered vehicles—albeit in ten years. But I wouldn't mind discussing improvements we could implement sooner in order to achieve cleaner air standards sooner.

And I wouldn't mind hearing why we have determined that hydrogen has become the fuel of choice to drive this mission. I am not saying it isn't the way to go. I would just like to discuss why it is the best option.

Further, I do not pretend to be a physicist or mechanical engineer. That is why I am glad we have the experts here to help us achieve a better understanding of these issues. I ask that we use this hearing to get a clearer map of where we are heading and why it is that that is the best direction in which to head. Thank you.

PREPARED STATEMENT OF HON. JOHN D. DINGELL, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF MICHIGAN

Mr. Chairman, I want to thank you for holding this important hearing. The industry must search for long-term ways to boost fuel economy substantially. Among those methods—10 to 20 years or more from now—the President's fuel cell program holds a lot of promise. The development of hydrogen fuel cell technologies is vital to the future competitiveness of the U.S. auto industry. Public-private partnerships, such as FreedomCAR and Michigan's Next Energy initiatives, are necessary to apply these developing technologies to practical uses and to adequately prepare the Nation's infrastructure to receive and support them.

For the immediate future, however, the answer is either hybrids or advanced clean burn diesel technology. The problem with hybrid electric technology is that its reliability and performance are unproven. The reliability and performance of clean burn diesel technology, on the other hand, has been well demonstrated.

Clean burn diesel technology is in wide use in the European Union (EU), the world's second largest vehicle market. Clean burn diesel vehicles accounted for 48 percent of all light-duty vehicles and 75 percent of all luxury vehicles sold in the EU last year. By 2010, diesels are expected to account for 75 percent of all light-duty vehicle sales in the EU.

One of the primary reasons this technology is so popular in Europe is that diesels have outstanding fuel economy. Audi's recently introduced A2 model has a fuel economy rating of 78 miles per gallon. The A2's mileage rating is better than that of the Honda Insight with its hybrid electric engine, and the A2 seats four passengers rather than the Honda's two passengers.

If diesel accounted for only 30 percent of California's fleet of motor vehicles, estimates are that fuel consumed by vehicles in California could be cut in half. If fuel consumed nationwide could be reduced by half, the Department of Energy says fuel consumption would be reduced to a level we haven't seen since November 1964.

Clean burn diesel engines are also very close to meeting U.S. emission standards. The motor vehicle companies have until 2007 to meet new nitrous oxide standards and the manufacturers believe they can do it.

None of these clean burn diesel vehicles, however, can be sold in the U.S., now or in the future, unless the U.S. cleans up its diesel fuel as the EU is doing. The U.S. allows 15 parts per million sulfur in its diesel fuel—not the six parts per million fuel that EPA used in its testing of the European Toyota.

Europe has been far more aggressive than the U.S. in banning sulfur from both gasoline and diesel fuels. Sweden has already adopted regulations allowing only "zero sulfur" diesel to be sold in that country. By 2005, the sulfur content of diesel fuel sold throughout the EU must be effectively "zero."

With essentially sulfur-free diesel fuel, recent advances in catalyst emission control technology make it possible to reduce nitrous oxide emissions from clean burn diesel engines by as much as 90 percent. Particulate emissions would also be greatly reduced with particulate trap technology. With clean burn diesel, hydrocarbon emissions are also much less than with current state-of-the-art gasoline engines.

Technology can be developed to make clean burn diesel engines meet U.S. standards, but it cannot happen without clean diesel fuel. U.S. refiners must take the sulfur out of diesel fuel just as the EU is doing. At the current U.S. standard of 15 parts per million, both the efficiency and durability of diesel engines is compromised to the point that the fuel economy advantages diesels offer cannot be realized.

All that blocks our path to high fuel economy here in the U.S., like the Audi A2's 78 miles per gallon, is dirty diesel fuel and the technology to overcome one test hurdle on nitrous oxide. Industry's engineers can overcome the nitrous oxide problem. But the motor vehicle industry can do nothing about cleaning up diesel fuel. That is a task only the Congress can handle.

I will be introducing legislation that requires refiners to produce lower sulfur diesel fuel. Because there will be investment and development costs associated with this requirement, my legislation will also provide for tax credits for the refining industry.

Diesel is the way of the future, and I am hopeful that its short-term benefits will not be overlooked by the Administration or the Congress, even as we examine longer term strategies.

Again, thank you for holding this hearing.

Mr. GREENWOOD. The Chair recognizes and welcomes our first panel, consisting of Mr. Jim Wells, who is the director of Natural Resources and Environment for the U.S. General Accounting Office; the Honorable David Garman, who is assistant secretary, Energy Efficiency and Renewable Energy at the U.S. Department of Energy; and Mr. Robert N. Culver, executive director of United States Council for Automotive Research. We welcome you all and thank you for helping us out this morning.

I believe you all are aware that this committee is holding an investigative hearing and it has had the practice of taking testimony under oath. Do any of you object to giving your testimony under oath? The Chair then advises you that under the rules of the House and the rules of the committee, you are entitled to be advised by counsel. Do any of you choose to be advised by counsel while you testify?

In that case if you'd please rise and raise your right hand, I'll swear you in.

[Witnesses sworn.]

Mr. GREENWOOD. Okay. Thank you. You are under oath, and we will recognize you for your opening statements, and we will begin with Mr. Wells.

TESTIMONY OF JIM WELLS, DIRECTOR, NATURAL RESOURCES AND ENVIRONMENT, U.S. GENERAL ACCOUNTING OFFICE; HON. DAVID K. GARMAN, ASSISTANT SECRETARY, ENERGY EFFICIENCY AND RENEWABLE ENERGY, U.S. DEPARTMENT OF ENERGY; AND ROBERT N. CULVER, EXECUTIVE DIRECTOR, UNITED STATES COUNCIL FOR AUTOMOTIVE RESEARCH

Mr. WELLS. Thank you, Mr. Chairman, and members. I too would like to begin my statement in an upbeat note, as you mentioned. We are pleased to be here to discuss the previous work on the Federal R&D initiatives that have provided some perhaps useful insight as the Congress considers the FreedomCAR initiative. As you know, gasoline consumption in the transportation sector is huge, 160 billion gallons a year. Given the reliance on petroleum, there's a high vulnerability to the uncertainties related to a world oil market. As a result, the Federal Government is and has been spending billions of dollars attempting to reduce the consumption of petroleum in the transportation sector. A variety of means have been tried. Tax incentives, mandates to use vehicles that run on alternative fuels and laws designed to enhance fuel efficiency.

More recently, the old last year's $1.2 billion partnership between industry and government as referred to the Partnership New Generation Vehicle, is being replaced with the new FreedomCAR initiative. Clearly, today's cars, Mr. Chairman, are more fuel efficient, and they are less polluting. The sad news is that any gains in fuel efficiency are being outpaced by the increase in the total miles that are being driven and the growing popularity of the sport utility vehicles and light trucks. We're using approximately 10-plus million barrels of petroleum a day to fuel these vehicles, and we're heading toward 15-plus million barrels in 2010.

As a result, I'd like you to look at the chart to my left here. It is also there in my printed statement. I draw your attention to that slender line at the top. This is the result so far in reducing petroleum usage. The largest dark-shaded area will show you two things: The annual petroleum usage is going up, increasing 40 billion gallons just in the last 10 years. You're looking at a 10-year period with billions of gallons to the left and 160 billion gallons at 2001. 97 percent of our transportation usage is gasoline, not alternative fuels.

That light-colored line that you see there at the top shows that we really haven't made much of a dent. Consumers have not widely embraced vehicles that run on anything other than gasoline. The challenge is going to be whether you build a car, a new hydrogen car and or whether you reduce the dependence on oil. Clearly these goals are going to be formidable goals. As Congress considers the FreedomCAR initiative or any comparative Federal-sponsored research program, we're here today to suggest, perhaps, four themes for Congressional oversight. These are based on some of the lessons we've learned as auditors in looking at these programs over 20 years.

The first one, make sure that the research being performed by private industry would not do on its own. Earlier, GAO had looked at work relating to the Department of Commerce's Advanced Technology Program. Forty percent of the participants in that program responded to the auditors that they would have performed the research even without Federal funding. A second theme, make sure the programs specify a clear and measurable goal.

Clearly, SEMATECH in the late 1980's, early 1990's, a Federal industry consortium, was successful because it clearly articulated both a goal that was improving the competitiveness of the U.S. manufacturer capability in semiconductors, and it did have a method to achieve this goal, and that was to build state-of-the-art semiconductors using only equipment manufactured in the United States.

Although the recent PNGV program began with a clear goal, they tried to develop a highly fuel efficient family sedan. The partnership struggled a little bit in not later reassessing the goal as consumers' tastes shifted away from the family sedans toward lighter trucks—light trucks and sport utility vehicles. The third theme that we bring to your attention is to ensure that all the new initiatives they devise a strategy to directly address the goal.

Although it may sound surprising, the government-sponsored R&D research programs over the years sometimes have articulated a goal and then not devised a strategy that directly addressed that goal. The classic case was the Energy Policy Act of 1992. It had a goal of reducing petroleum fuel reduction, but it also allowed a strategy to be put in place instructing the Federal agencies to buy alternative fuel vehicles, which ended up being powered by gasoline, and as a result, achieved no fuel reductions.

As you consider the FreedomCAR initiative, it's important to recognize as was the case with alternative fuels and was mentioned by the chairman, that there is a lack of infrastructure for fuels other than gasoline. Look at these charts. The question will be asked, how far are you willing to drive to find fuel? The top chart represents gasoline infrastructure. The bottom chart represents filling stations related to alternative fuels. This lack of infrastructure could pose a very significant challenge to the implementation of any kind of FreedomCAR-type initiative when the vehicles it develops will run on anything other than gasoline.

And my last theme would be to consider whether consumers will buy the product resulting from the R&D expenditure and efforts that you put forth. We've seen that Federal research sometimes producing compelling technical accomplishments but few marketable products. In 1995, we reported the U.S. advanced battery consortium could potentially achieve its immediate technical goals, and they did, but the resulting batteries would be too expensive, and would not enable the electric cars that were equipped with these batteries to be competitive with the traditional automobiles.

Mr. Chairman, in conclusion, the FreedomCAR initiative plan to develop fuel cell technology clearly, in our opinion, represents an exciting area of research. The payoff could be large. As auditors based on our earlier reviews, it would be critical for the initiative to keep one eye on achieving technical goals, and also to keep one eye particularly on the marketplace. Moreover, if there's one thing I want to leave you with, the ultimate success of how this new FreedomCAR initiative may be judged in the future, it may be judged not by the specific technical goals that it achieves along the way, but by its contribution toward enlarging that slim sliver of a line that I showed you earlier on the chart that represents future nonpetroleum usage.

Mr. Chairman, that concludes my summary, remarks, and will be glad to answer questions at a later time. Thank you.

[The prepared statement of Jim Wells appears at the end of the hearing.]

Mr. GREENWOOD. Thank you, Mr. Wells. We appreciate your testimony and we'll now turn to Mr. Garman.

STATEMENT OF DAVID K. GARMAN

Mr. GARMAN. Thank you, Mr. Chairman. I appreciate the opportunity to discuss FreedomCAR, which is an initiative to reduce the Nation's dependence on foreign oil by dramatically changing how we will 1 day power our cars and light trucks. This light illustrates the expanding gap between declining domestic oil production and our increasing demand, even if we open ANWR, a business-as-usual approach, to research and development does not close the gap. Mindful of this fact, Secretary Abraham challenged us to take a bolder approach to our work. He challenged us to leapfrog the status quo and pursue dramatic environmental benefits.

On January 9, Secretary Abraham, joined by top leadership of General Motors, Daimler-Chrysler and Ford announced FreedomCAR at the North American International Auto Show in Detroit. The "CAR" in FreedomCAR stands for "cooperative automotive research," and the "Freedom" concept represents our fundamental long-term goals for this program: Freedom from petroleum dependence, freedom from pollutant emissions, freedom for Americans to choose the kind of car they want to drive and to drive where they want when they want.

In short, we're looking to eventually remove the automobile as a factor in the environmental equation and as a factor that drives our dependency on foreign petroleum. If we want all of these things as well as performance functionality and affordability in a wide range of vehicles, we see the most promising long-term approach is hydrogen-fueled fuel cells combined with electric drive. Therefore, the first element of our strategic approach is to develop technologies enabling mass production of affordable fuel cell vehicles and to assure the hydrogen infrastructure to support those vehicles.

The partnership we've enjoyed in the past, the Partnership for a New Generation of Vehicles, had some successes, and we're certainly not abandoning them. Indeed many of the research elements of the PNGV program are embodied in the second element of our approach to continue support for hybrid and other technologies that can dramatically reduce oil consumption and environmental impacts in the near term.

The third element of our strategic approach is to develop technologies applicable across a wide range of passenger vehicles. One of the problems with the PNGV program was it focused on a production prototype of a family sedan. We're not limiting our focus.

In its most recent peer review of the PNGV program, the National Academy of Science has made a number of observations and recommendations. They suggested that PNGV goals be re-examined. They observed that the real opportunities for saving energies are in increasing the efficiencies of sport utility vehicles and pickups. They cautioned that it's inappropriate for government to be involved in the development of production prototypes. And we took their advice to heart and made changes.

With respect to key goals, FreedomCAR is focused on petroleum-free, emissions-free transportation with an emphasis on hydrogen fuel cells and also on systems and components applicable to many types of vehicles. PNGV was focused on a production prototype 80-mile-per-gallon family sedan. With respect to timeframe, FreedomCAR has a long-term vision with component technology goals over the next 10 years to gauge our progress. PNGV was a 10-year program focused on 2004.

With respect to government leadership and focus, FreedomCAR is a partnership solely between DOE and USCAR. PNGV was a collaboration between USCAR and seven government agencies led by the Department of Commerce. With respect to technology emphasis, FreedomCAR is focused on hydrogen and fuel cells with transitional efficiency gains from advanced combustion and fuel processors. PNGV emphasized compression, ignition, direct injection hybrids. With respect to vehicle focus, FreedomCAR's focus is R&D at the component level with equal emphasis on cars and light trucks. PNGV emphasized development and demonstration of preproduction, mid-sized family sedans. We're not abandoning the good work that has emerged from PNGV.

There are many shared components between an advanced hybrid electric vehicle and a fuel cell vehicle including light-weight materials, power electronics, electric motors and batteries. Advances we make in these components need not wait for fuel cells or hydrogen infrastructure to reach the market, as they can be introduced as soon as they're ready. We'll also be continuing our work in alternative fuel and advanced combustion engines needed to support the development of advanced hybrid electric vehicles.

Of course, new areas of emphasis needed for fuel cell vehicles include hydrogen storage, on-board reformation and fuel cell stack development. This is our budget cross-cut for FreedomCAR. We're proposing to spend $150.3 million on this initiative in fiscal year 2003. And a lot has been said about specific technology goals. The transition to a hydrogen-based transportation system is a long-range vision.

To assure progress, intermediate goals are necessary to ensure that these accomplishments can be measured and our progress can be measured along the way. We have goals to ensure reliable affordable fuel cell power trains. We have goals to promote energy efficient vehicles operating on hydrocarbon-based fuels to be powered either by internal combustion power trains or fuel cells. We have goals focused on improving hybrid durability and affordability. We have goals focused on the need for a widespread availability of hydrogen fuels. We have goals designed to assure vehicle functionality. We have goals designed to improve the manufacturing base, and we also have goals geared to performance-based management.

In summary, our vision for FreedomCAR is a bold one in response to Secretary Abraham's challenge that we act boldly. Although FreedomCAR is a long-term effort beyond any near-term political horizon, we've developed intermediate goals to ensure that we make measurable demonstrable progress toward our vision in the coming decade. Thank you, Mr. Chairman.

[The prepared statement of David K. Garman follows:]

PREPARED STATEMENT OF DAVID K. GARMAN, ASSISTANT SECRETARY FOR ENERGY EFFICIENCY AND RENEWABLE ENERGY, U.S. DEPARTMENT OF ENERGY

Mr. Chairman, I appreciate this opportunity to discuss FreedomCAR—our flagship research and development initiative to reduce the nation's dependence on foreign oil by dramatically changing how we power our cars and light trucks.

By way of background, the most striking feature of our transportation system is its nearly complete dependence on petroleum as an energy source. Petroleum is used to satisfy 95% of America's transportation energy needs, consuming two-thirds of all the petroleum we use. Since roughly 55% of our petroleum is imported from abroad, the implications of this dependency on our energy security are well understood by the members of this Committee, and I need not dwell on them here.

THE "GAP" IS GROWING

This slide illustrates the expanding gap between declining domestic oil production and our increasing demand. As you can see, opening the Coastal Plain of the Arctic National Wildlife Refuge to exploration would clearly help, but that alone would not close the gap. The R&D approach we were previously embarked on would have also helped . . . but would not have closed the gap either. Indeed, both taken together would not have closed the gap.

Mindful of these realities, Secretary Abraham challenged the Department of Energy to take a bolder approach to our work. He directed us to focus our efforts on programs that "revolutionize how we approach conservation and energy efficiency." He challenged us to "leapfrog the status quo" and to pursue "dramatic environmental benefits."

FREEDOMCAR IS A PARTNERSHIP

On January 9, 2002, Secretary Abraham, joined by top leadership from General Motors, Daimler Chrysler, and Ford, announced FreedomCAR at the North American International Auto Show in Detroit.

The CAR in FreedomCAR stands for Cooperative Automotive Research. And the "Freedom" concept represents our fundamental, long-term goals for this program:

- Freedom from petroleum dependence;
- Freedom from pollutant emissions;
- Freedom for Americans to choose the kind of vehicle they want to drive, and to drive where they want, when they want; and
- Freedom to obtain fuel affordably and conveniently.

We are seeking to develop cars and trucks that are free of foreign oil and harmful emissions, without sacrificing safety, freedom of mobility and freedom of vehicle choice. We are looking to eventually remove the automobile as a factor in the environmental equation, and as a factor that drives our dependency on foreign petroleum.

This is a dramatic, far reaching vision . . . one that requires new technology. We cannot break the bonds of oil dependency by continuing with the status quo. Given the low gasoline and diesel prices we enjoy today, we can reasonably expect consumers to continue demanding larger, heavier, more powerful vehicles, and vehicle manufacturers to continue using internal combustion engines to satisfy that demand. We clearly see this in the marketplace today. The majority of the new passenger vehicles sold in 2001 were, for the very first time in automotive history, light trucks in the form of sport utility vehicles, vans and pickups.

STRATEGIC APPROACH

How is it possible to offer performance, convenience and functionality in a range of vehicles that can meet the needs of a diverse population without using petroleum? We believe the most promising long-term approach is to employ hydrogen fuel cells combined with electric drive.

Therefore, the first element of our strategic approach is to develop technologies to enable mass production of affordable hydrogen-powered fuel cell vehicles and assure the hydrogen infrastructure to support them.

Fuel cells, of course, can be thought of as batteries that are continuously replenished by a constant supply of hydrogen. And hydrogen, the most plentiful element in the universe and the third most plentiful on earth, can be derived from a variety of sources including petroleum, natural gas, coal, biomass, and even water.

But there are significant technical and infrastructure barriers that must be overcome, including fuel cell cost and durability; electric drive performance and cost; hydrogen production, storage, cost and distribution challenges; and many others. Neither industry nor government, working alone, is likely to overcome these barriers in any reasonable timeframe. Therefore, we must work in partnership.

The partnership we have enjoyed in the past, the Partnership for a New Generation of Vehicles (PGNV), has had some successes, and we are certainly not abandoning those successes or the collaborations it fostered. Indeed, many of the research elements of PNGV are embodied in the second element of our approach: Namely, to continue support for hybrid technologies and advanced materials that can dramatically reduce oil consumption and environmental impacts in the nearer term.

But one of the problems of PNGV was its focus on a production prototype of a family sedan. Therefore, the third element of our strategic approach is to develop technologies applicable across a wide range of passenger vehicles.

NATIONAL ACADEMY OF SCIENCES OBSERVATIONS AND RECOMMENDATIONS

In its most recent peer review of the PNGV program, the National Academy of Sciences made a number of observations and recommendations, a few of which I will list here:

- "[T]he priorities and specific goals of the PNGV program should be reexamined. There is a need to update the program goals and technical targets in the context of current and prospective markets . . . government and industry participants should refine the PNGV charter and goals."
- "[T]he demand for sport utility vehicles, vans, and pickup trucks in the United States has drastically increased . . . This has increased the importance of reducing the fuel consumption of these vehicles compared to the typical family sedan."
- "If the program goal (sic) were refocused on reducing total new light duty vehicle petroleum consumption, this would encourage the emphasis to be placed on those vehicles that offer the greatest potential for achieving this societal goal."
- ". . . it is inappropriate to include the process of building production prototypes in a precompetitive, cooperative industry-government program."

FREEDOMCAR DIFFERS FROM PNGV

We have accordingly made changes responsive to the observations and recommendations of the peer review panel. With respect to key goals: FreedomCAR is focused on petroleum free, emissions free transportation, with emphasis on hydrogen fuel cells. PNGV was focused on building a production prototype 80 mile-per-gallon family sedan.

With respect to timeframe: FreedomCAR has a long-term vision with 2010 component technology goals to gauge progress. PNGV was a 10-year program focused on 2004.

With respect to government leadership and focus: FreedomCAR is a partnership solely between DOE and USCAR.

PNGV was a collaboration between USCAR and seven government agencies led by the Department of Commerce.

With respect to technology emphasis: FreedomCAR is focused on hydrogen and fuel cells, with transitional efficiency gains from advanced combustion and fuel processors. PNGV emphasized compression ignition direct injection (diesel) hybrids.

With respect to vehicle focus: FreedomCAR's focus is R&D at the component level with equal emphasis on light trucks and cars. PNGV emphasized development and demonstration of pre-production mid-sized family sedans.

FREEDOMCAR AND HYBRIDS SHARE TECHNOLOGY

Let me again emphasize that we are not abandoning the good work that has emerged from PNGV. There are many shared components between an advanced hybrid electric vehicle and a fuel cell vehicle, including lightweight materials, power electronics, electric motors, and batteries. Breakthroughs we make in these components need not wait for fuel cells or hydrogen infrastructure to reach the market, as they can be employed as soon as they are ready.

We will also be continuing our work in alternative fuels and advanced combustion engines (including emissions controls R&D) that are needed to support the development of advanced hybrid electric vehicles.

FUEL CELL VEHICLE COMPONENTS

Of course, new areas of emphasis aboard the vehicle include hydrogen storage, onboard reformation, and fuel cell stack development.

But we are also beginning to address the technologies necessary to make a transition to a hydrogen-based transportation economy. Principal among these efforts will be solving the problems associated with producing and making hydrogen fuel widely available. To that end, elements of the hydrogen program in the Office of Power Technologies (OPT) are being integrated into the FreedomCAR effort. Efforts by DOE's Fossil Energy office on deriving hydrogen from coal (with sequestered carbon) are also being reviewed. In addition, a related effort in OPT on hydrogen-fueled internal combustion engines is under consideration for inclusion.

In November of 2001 my office convened senior executives representing energy industries, environmental organizations and government officials to discuss the role for hydrogen systems in America's energy future. This group addressed a common vision for the hydrogen economy, the time frame for the vision and the key milestones needed to get there. There was general agreement that hydrogen can be America's clean energy choice, and that the transition to a hydrogen future has already begun but could well take 40-50 years to fully unfold. We are working on a specific technology roadmap covering production, storage, conversion and infrastructure that leads us to that vision, and we are continuing that work as a part of the FreedomCAR program plan.

FREEDOMCAR RESEARCH COMPONENTS AND SPENDING LEVELS

My next slide shows our budget crosscut for FreedomCAR. We are proposing to spend $150.3 million on this initiative in FY 2003. The most notable changes in the FY 2003 budget are: 1) increased funding for vehicle fuel cell R&D of $8.075 million, to a level of $50 million, and 2) increased funding for hydrogen generation, transport and fueling infrastructure by $9.659 million relative to FY 2002 appropriation levels.

Whereas PNGV was a multi-agency partnership, the only Federal partner in FreedomCAR is the Department of Energy. Since the inception of PNGV, DOE has accounted for most of the government's contributions. In FY 2001, we provided 86 percent of the funding that was directly relevant to the PNGV goals, and that was linked with the plans developed by the PNGV government-industry technical teams. While other agencies are not formally involved as FreedomCAR partners, we intend to coordinate our work with the appropriate technology research, development and demonstration programs managed by other Federal agencies, and by State governments as well. The mechanisms by which coordination is accomplished will be worked out during the next few months.

SPECIFIC TECHNOLOGICAL GOALS AND TIMETABLES

The transition to a hydrogen-based transportation system is a long-range vision. To assure progress, nearer-term goals are necessary so that accomplishments can be measured and recognized. Therefore, the Partnership has identified the following 2010 technology-specific goals.[1]

2010 TECHNOLOGY GOALS: FUEL CELL POWERTRAINS

• To ensure reliable systems for future fuel cell powertrains with costs comparable to conventional internal combustion engine/automatic transmission systems, the goals are:

- Electric Propulsion System with a 15-year life capable of delivering at least 55kW for 18 seconds, and 30kW continuous at a system cost of $12/kW peak.
- 60% peak energy-efficient, durable fuel cell power system (including hydrogen storage) that achieves a 325 W/kg power density and 220 W/L operating on hydrogen. Cost targets are at $45/kW by 2010 ($30/kW by 2015).[2]

2010 TECHNOLOGY GOALS: HYDROCARBON FUEL PLATFORM

• To enable clean, energy-efficient vehicles operating on clean, hydrocarbon-based fuels powered by either internal combustion powertrains or fuel cells, the goals are:

- Internal combustion engine powertrain systems costing $30/kW, having a peak brake engine efficiency of 45%, and that meet or exceed emissions standards.
- Fuel cell systems, including a fuel reformer, having a peak brake engine efficiency of 45%, and that meet or exceed emissions standards with a cost target of $45/kW by 2010 and $30/kW in 2015.[2,3]

2010 TECHNOLOGY GOAL: HYBRID SYSTEMS

• To enable reliable hybrid electric vehicles that are durable and affordable, the goal is:

- Electric drivetrain energy storage with 15-year life at 300 Wh with discharge power of 25 kW for 18 seconds and $20/kW.

2010 TECHNOLOGY GOALS: HYDROGEN TRANSITION

• To enable the transition to a hydrogen economy, ensure widespread availability of hydrogen fuels, and retain the functional characteristics of current vehicles, the goals are:

- Demonstrated hydrogen refueling with developed commercial codes and standards and diverse renewable and non-renewable energy sources. Targets: 70% energy efficiency well-to-pump; cost of energy from hydrogen equivalent to gasoline at market price, assumed to be $1.25 per gallon (2001 dollars).[4]

- Hydrogen storage systems demonstrating an available capacity of 6 weight percent hydrogen, specific energy of 2000 W-h/kg, energy density of 1100 W-h/liter at a cost of $5/kWh.[5]
- Internal combustion engine powertrain systems operating on hydrogen with a cost target of $45/kW by 2010 and $30/kW in 2015, having a peak brake engine efficiency of 45%, and that meet or exceed emissions standards.

2010 TECHNOLOGY GOALS: MANUFACTURING BASE

- To improve the manufacturing base, the goal is:
- Material and manufacturing technologies for high volume production vehicles which enable/support the simultaneous attainment of:
  - 50% reduction in the weight of vehicle structure & subsystems,
  - affordability, and
  - increased use of recyclable/renewable materials.

PERFORMANCE BASED MANAGEMENT

- Key metrics to be tracked annually
- 2010 goals supported by targets and milestones detailed in EERE's Budget Request
- All FreedomCAR work to be assessed annually against the R&D investment criteria developed as part of the President's Management Agenda

I understand that these goals are highly technical, and they all have a target year of 2010. I also understand that the NAS criticized PNGV for not developing interim milestones for its ten-year "stretch" goals. Therefore, we are developing a suite of easily understandable key metrics that can be presented graphically and will be tracked annually so that we can measure our progress.

We have also developed numerous supporting objectives for the various sub-programs that will contribute to the FreedomCAR goals. We have identified an easily quantifiable performance indicator for each of these objectives to ensure that all of the sub-programs are making progress.

In addition, as with all DOE applied R&D programs, FreedomCAR R&D will be assessed annually against the R&D investment criteria developed as part of the President's Management Agenda to ensure that the R&D:

- Does not drift into areas that are inappropriate for Federal investment
- Will maintain strong merit and is well planned
- Is producing beneficial results

Furthermore, FreedomCAR R&D will strictly follow the cost-sharing guidelines developed with the Administration's R&D investment criteria.

CONCLUSION

Mr. Chairman, our vision for FreedomCAR is a bold one, in response to Secretary Abraham's challenge that we act boldly to "revolutionize how we approach conservation and energy efficiency."

FreedomCAR is clearly a long-term effort beyond any near-term political horizon. But even as we pursue our ultimate vision of emissions-free, petroleum-free, safe and affordable transportation, we have developed near-term goals to ensure that we make measurable, demonstrable progress toward that vision in the coming decade.

And again, while we do face significant technology and infrastructure risks, the exceptional rewards and national benefits we could achieve justifies the effort.

I welcome your questions.

References

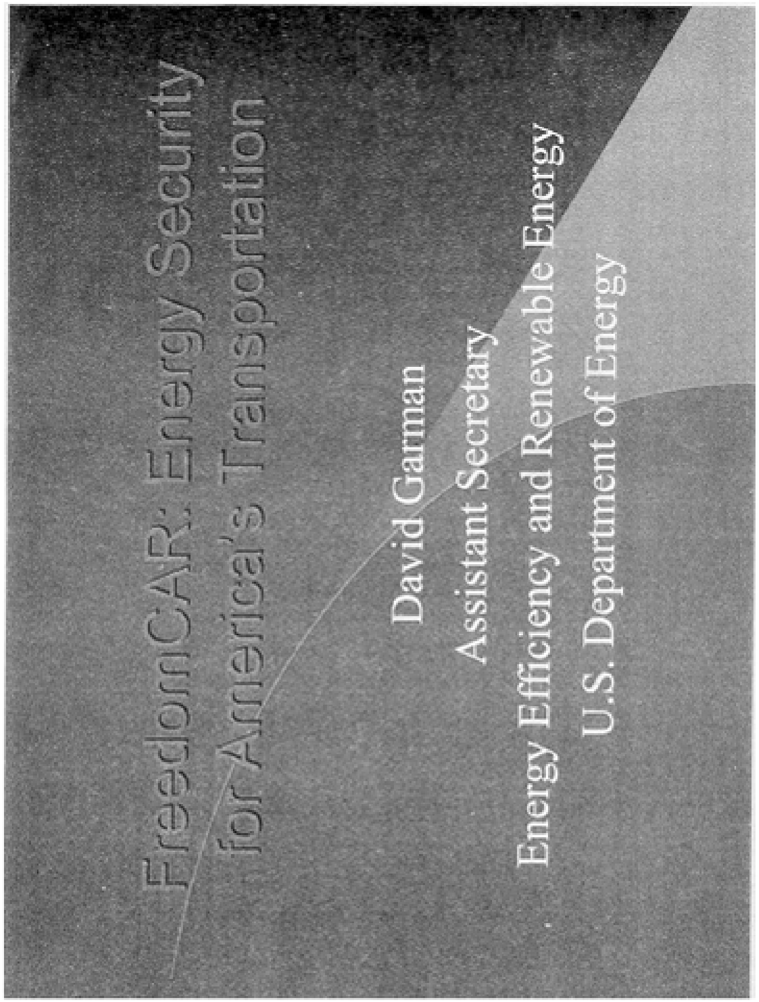
[1] Cost references based on CY 2001 dollar values. Where power (kW) targets are specified, those targets are to ensure that technology challenges that would occur in a range of light-duty vehicle types would have to be addressed.

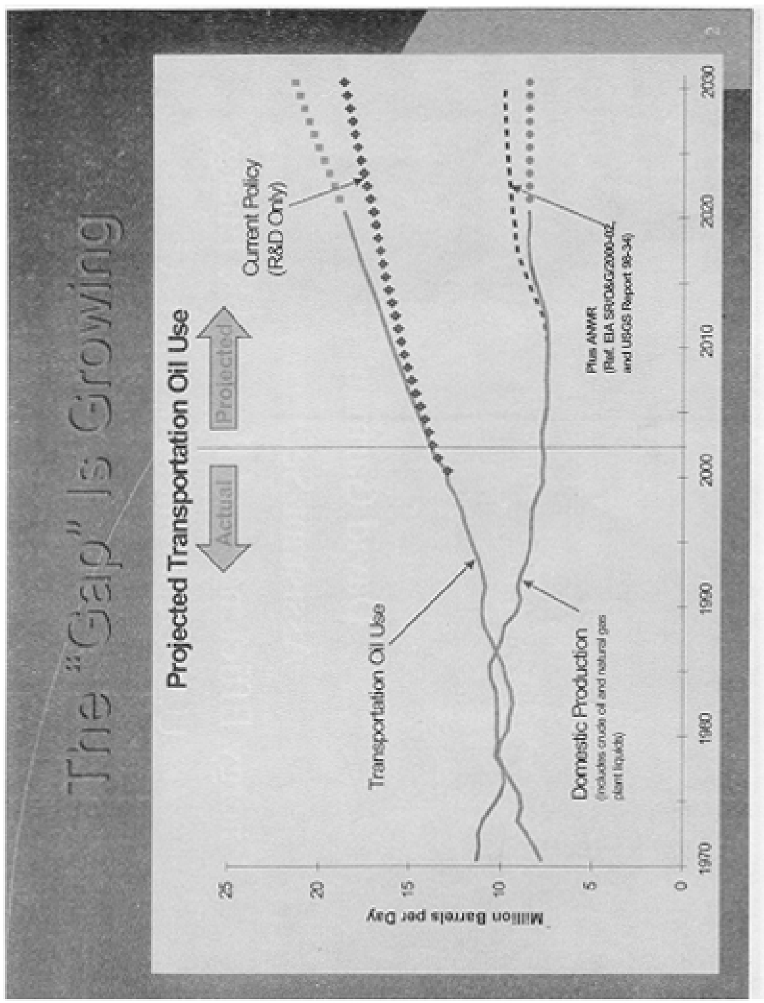
[2] Does not include vehicle traction electronics.

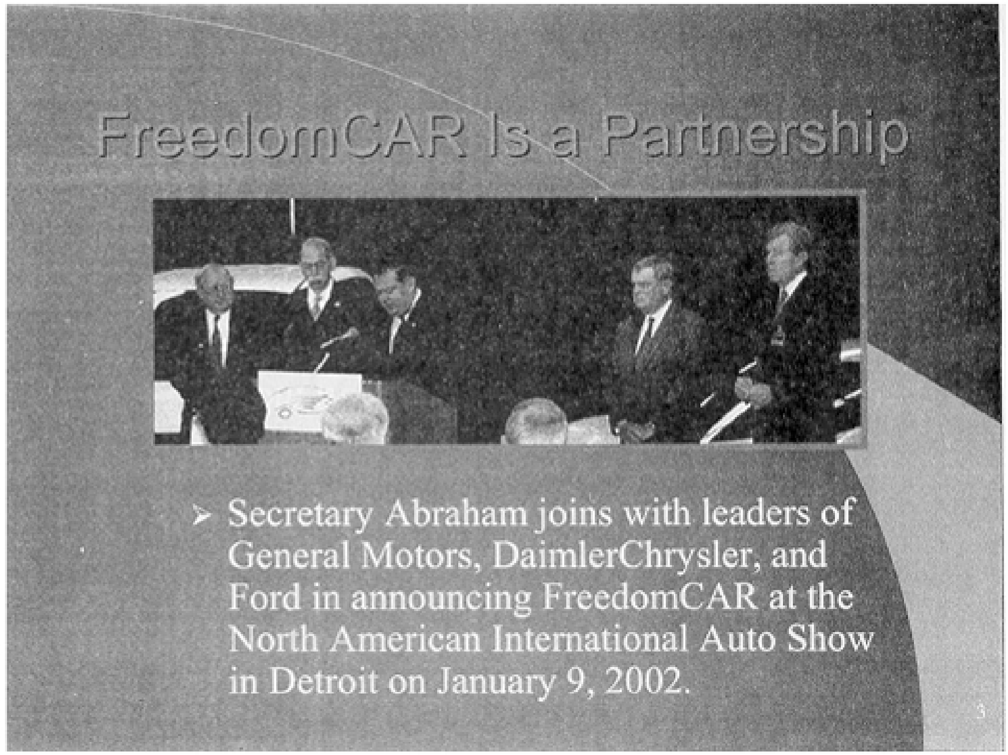
[3] Includes fuel cell stack subsystem, fuel processor subsystem and auxiliaries; does not include fuel tank.

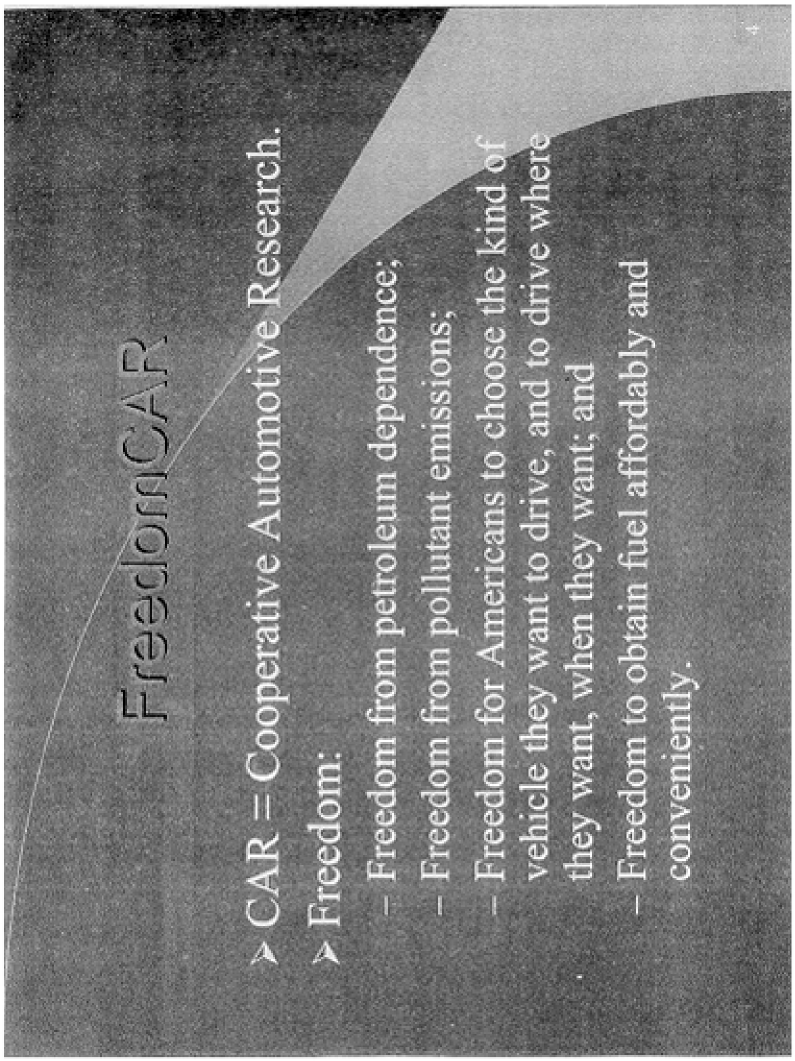
[4] Targets are for hydrogen dispensed to a vehicle assuming a reforming, compressing and dispensing system capable of dispensing 150 kilograms per day (assuming 60,000 SCF per day of NG is fed for reforming at the retail dispensing station) and servicing a fleet of 300 vehicles per day (assuming 0.5 kgs used in each vehicle per day). Targets are also based on several thousand stations, and possibly demonstrated on several hundred stations. Technologies may also include chemical hydrides such as sodium boro-hydride.

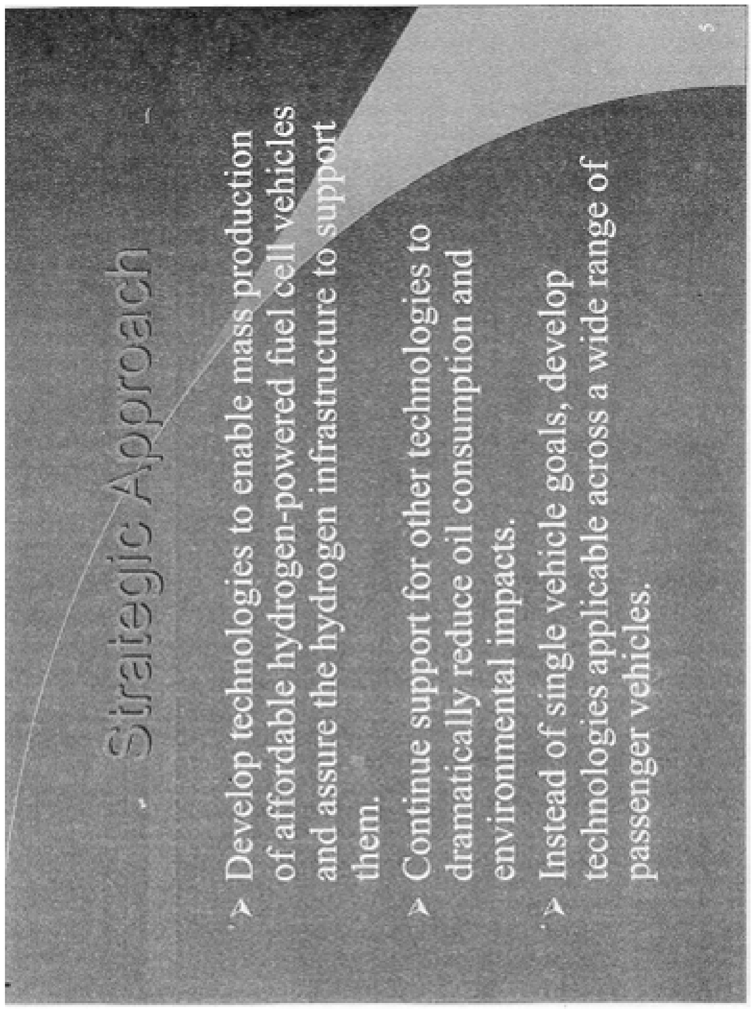
[5] Based on lower heating value of hydrogen; allows over 300-mile range.


FreedomCAR: Energy Security
for America's Transportation
David Garman
Assistant Secretary
Energy Efficiency and Renewable Energy
U.S. Department of Energy

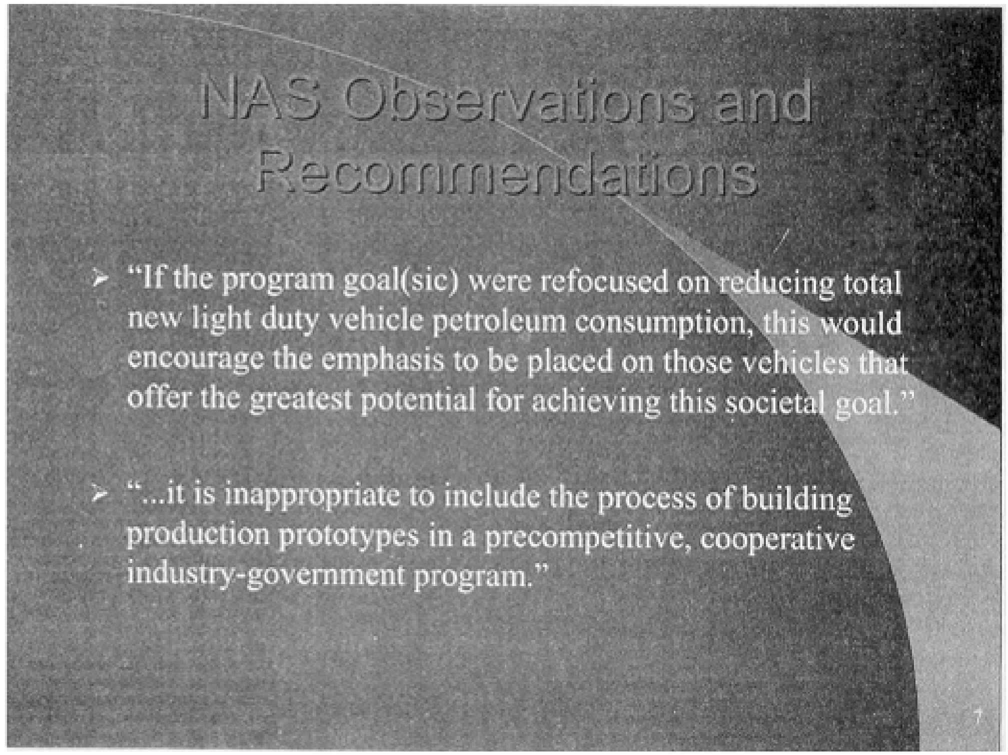

The "Gap" Is Growing
Projected Transportation Oil Use
Actual
Projected
Million Barrels per Day
25
20
15
10
5
0
1970
1980
1990
2000
2010
2020
2030
Transportation Oil Use
Domestic Production
(Includes crude oil and natural gas plant liquids)
Current Policy
(R&D Only)
Plus ANWR
(Ref. EIA SR/O&G/2000-02, and USGS Report 98-34)

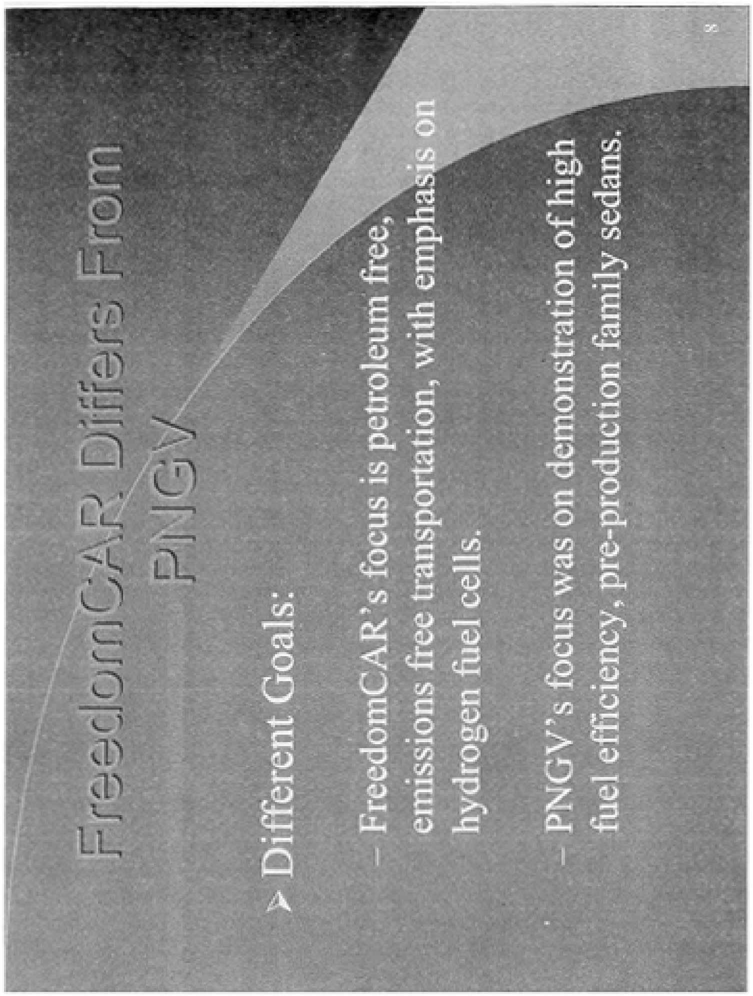

FreedomCAR Is a Partnership
➢ Secretary Abraham joins with leaders of General Motors, DaimlerChrysler, and Ford in announcing FreedomCAR at the North American International Auto Show in Detroit on January 9, 2002.
3


FreedomCAR
➢ CAR = Cooperative Automotive Research.
➢ Freedom:
– Freedom from petroleum dependence;
– Freedom from pollutant emissions;
– Freedom for Americans to choose the kind of vehicle they want to drive, and to drive where they want, when they want; and
– Freedom to obtain fuel affordably and conveniently.
4


Strategic Approach
Develop technologies to enable mass production of affordable hydrogen-powered fuel cell vehicles and assure the hydrogen infrastructure to support them.
Continue support for other technologies to dramatically reduce oil consumption and environmental impacts.
Instead of single vehicle goals, develop technologies applicable across a wide range of passenger vehicles.
5

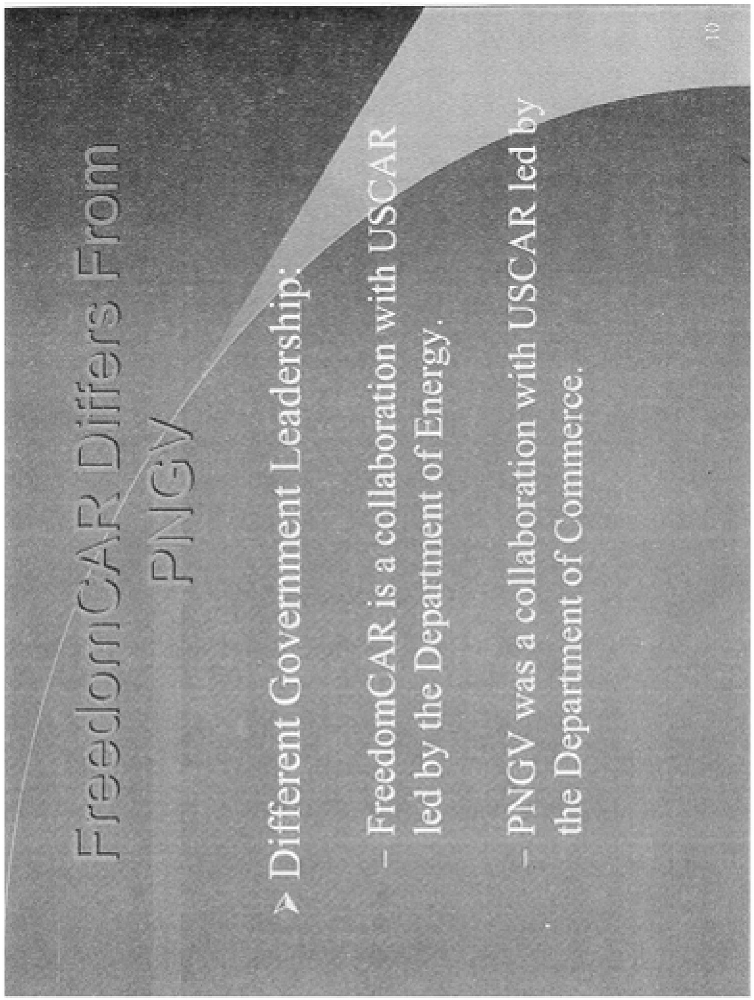

NAS Observations and Recommendations
"[T]he priorities and specific goals of the PNGV program should be reexamined. There is a need to update the program goals and technical targets in the context of current and prospective markets ... government and industry participants should refine the PNGV charter and goals."
"[T]he demand for sport utility vehicles, vans, and pickup trucks in the United States has drastically increased ... This has increased the importance of reducing the fuel consumption of these vehicles compared to the typical family sedan."
6


NAS Observations and Recommendations
➢ "If the program goal(sic) were refocused on reducing total new light duty vehicle petroleum consumption, this would encourage the emphasis to be placed on those vehicles that offer the greatest potential for achieving this societal goal."
➢ "...it is inappropriate to include the process of building production prototypes in a precompetitive, cooperative industry-government program."


FreedomCAR Differs From PNGV
Different Goals:
– FreedomCAR's focus is petroleum free, emissions free transportation, with emphasis on hydrogen fuel cells.
– PNGV's focus was on demonstration of high fuel efficiency, pre-production family sedans.
8

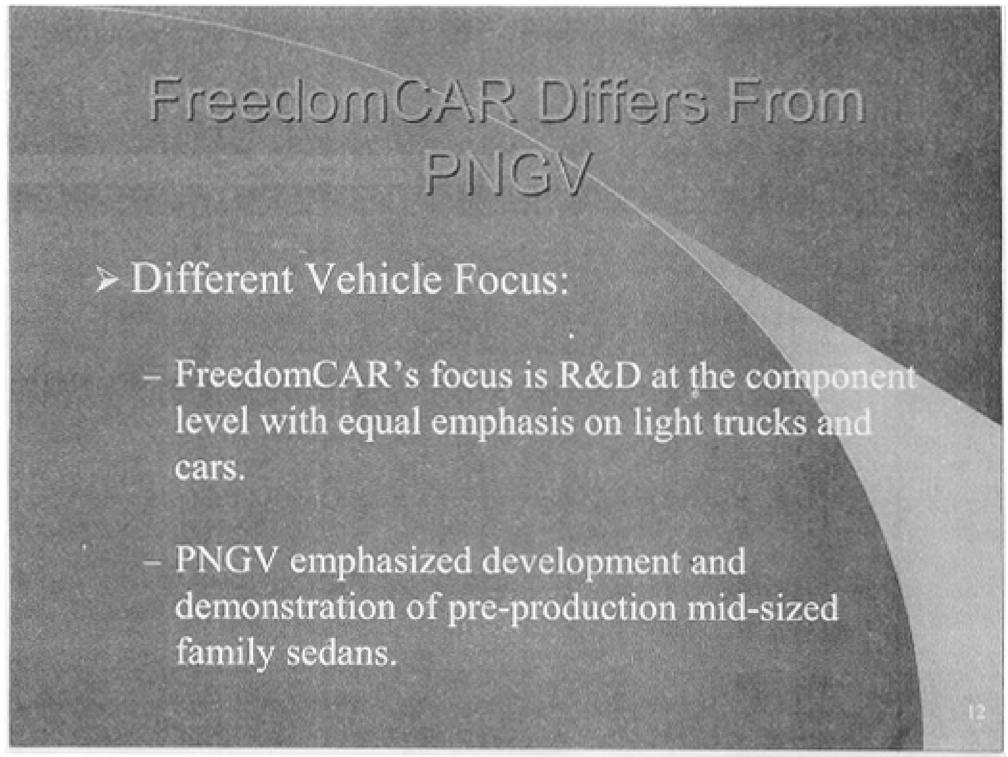
FreedomCAR Differs From PNGV

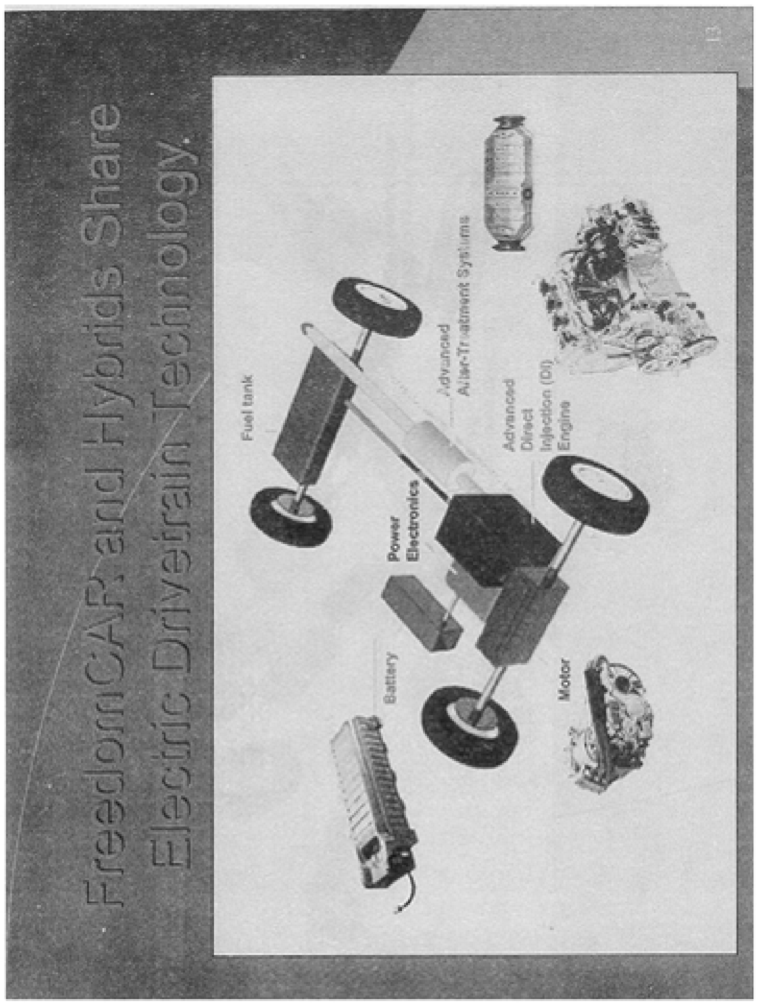
- Different Timeframe:
  - FreedomCAR has a long-term vision with intermediate 2010 component technology goals to measure progress.
  - PNGV time frame was focused on 2004.


FreedomCAR Differs From PNGV
Different Government Leadership:
– FreedomCAR is a collaboration with USCAR led by the Department of Energy.
– PNGV was a collaboration with USCAR led by the Department of Commerce.
10

FreedomCAR Differs From PNGV

- Different Technology Emphasis:
  - FreedomCAR is focused on hydrogen and fuel cells, with transitional efficiency gains from advanced combustion and fuel processors.
  - PNGV emphasized compression ignition direct injection (diesel) hybrids.


FreedomCAR Differs From PNGV
➢ Different Vehicle Focus:
– FreedomCAR's focus is R&D at the component level with equal emphasis on light trucks and cars.
– PNGV emphasized development and demonstration of pre-production mid-sized family sedans.
12


FreedomCAR and Hybrids Share
Electric Drivetrain Technology
Fuel tank
Advanced
After-Treatment Systems
Advanced
Direct
Injection (DI)
Engine
Power
Electronics
Battery
Motor
13


Fuel Cell Vehicle Components
High-pressure hydrogen storage tank or
Fuel storage and reformer or other storage options
FC Stack
Power Electronics
Air Compressor
Battery
Motor
14

Budget Crosscut

	PNGV		FreedomCAR
	FY 2001 a/ b/ Comparable Appropriations for PNGV Tier 1	FY 2002 b/ Comparable Appropriations for PNGV Tier 1	FY 2003 b/ Request
Office of Energy Efficiency and Renewable Energy Total	[illegible]	[illegible]	[illegible]
Transportation Sector Funding Supporting FreedomCAR	138,982	128,583	124,470
A. Vehicle Technologies R&D	109,232	99,531	107,076
1. Hybrid Systems R&D	45,060	41,615	38,500
2. Fuel Cell R&D	40,083	41,825	50,000
3. Advanced Combustion Engine R&D	22,589	15,591	14,076
4. Cooperative Automotive Research for Advanced Technologies (CARAT)	1,500	500	1,000
5. Electric Vehicles R&D			3,500
B. Fuels Utilization R&D	6,956	6,340	5,800
1. Advanced Petroleum Based Fuels	5,974	5,340	5,300
2. Alternative Fuels	982	1,000	500
C. Materials Technologies	21,454	18,441	10,600
1. Propulsion Materials Technology	2,936	2,581	1,000
2. Lightweight Materials Technology	18,518	15,860	9,600
D. Technology Deployment: Advance Vehicle Competitions	840	800	1,099
Hydrogen Program Funding Supporting FreedomCAR			25,926
A. Core R&D			15,598
B. Technology Validation			7,998
C. Analysis and Outreach			2,330

a/ FY 2001 appropriations have been adjusted to reflect the .22% omnibus rescission and an appropriation transfer for the Small Business Innovation Research (SBIR) and the Small Business Technology Transfer Pilot Program (STTR).

b/ Totals do not include administrative expenses.

15

2010 Technology Goals: Fuel Cell Powertrains

- Electric Propulsion System with a 15-year life capable of delivering at least 55kW for 18 seconds, and 30kW continuous at a system cost of $12/kW peak.
- 60% peak energy-efficient, durable fuel cell power system (including hydrogen storage) that achieves a 325 W/kg power density and 220 W/L operating on hydrogen. Cost targets are at $45/kW by 2010 ($30/kW by 2015).

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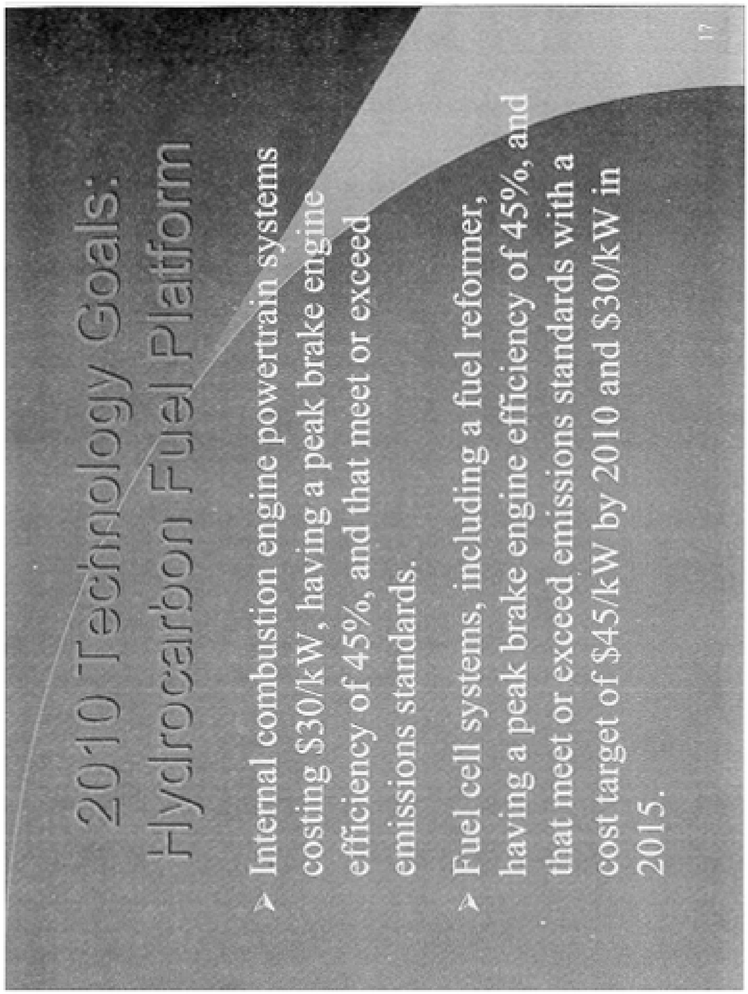
2010 Technology Goals:
Hydrocarbon Fuel Platform
Internal combustion engine powertrain systems costing $30/kW, having a peak brake engine efficiency of 45%, and that meet or exceed emissions standards.
Fuel cell systems, including a fuel reformer, having a peak brake engine efficiency of 45%, and that meet or exceed emissions standards with a cost target of $45/kW by 2010 and $30/kW in 2015.
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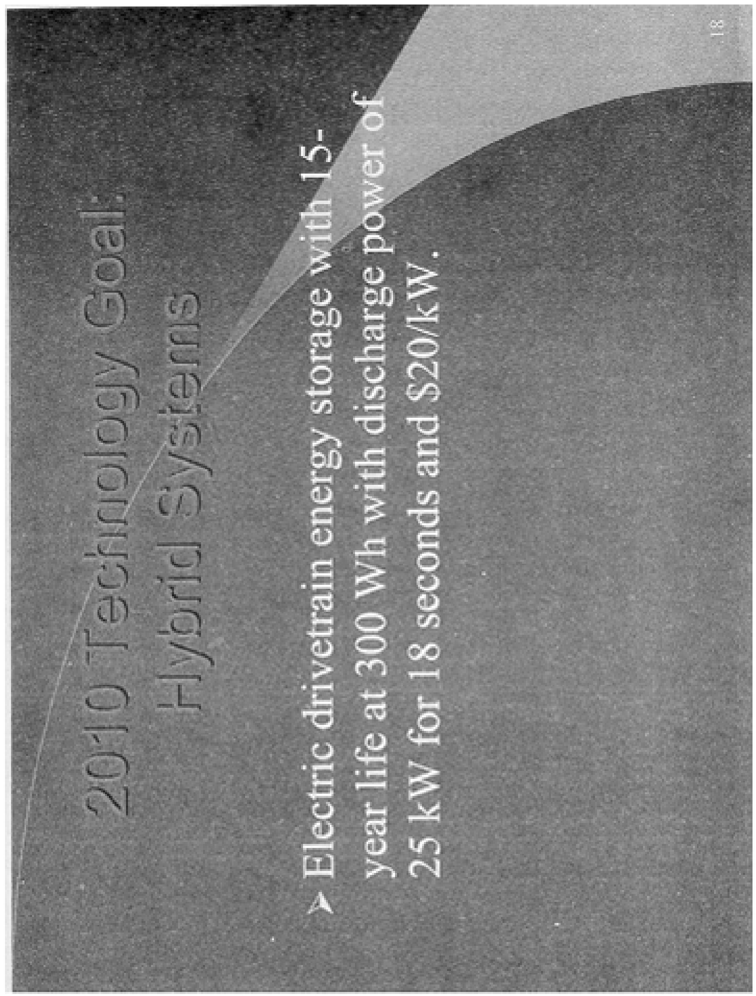
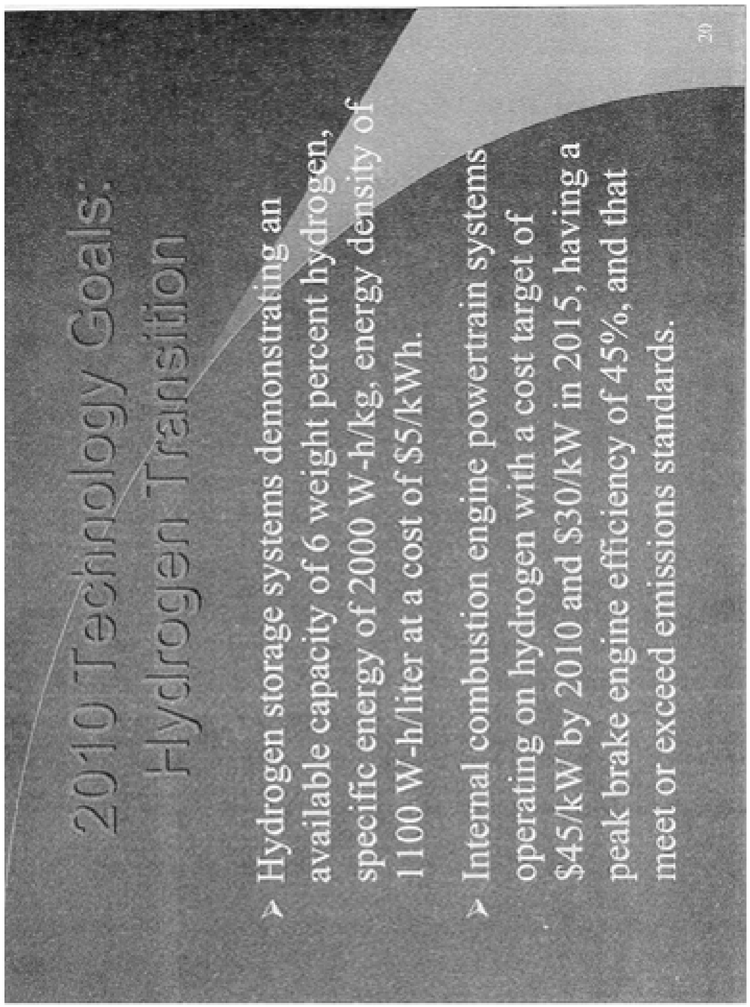

2010 Technology Goal:
Hybrid Systems
➤ Electric drivetrain energy storage with 15-year life at 300 Wh with discharge power of 25 kW for 18 seconds and $20/kW.
18

2010 Technology Goals: Hydrogen Transition

- Demonstrated hydrogen refueling with developed commercial codes and standards and diverse renewable and non-renewable energy sources. Targets: 70% energy efficiency well-to-pump; cost of energy from hydrogen equivalent to gasoline at market price, assumed to be $1.25 per gallon (2001 dollars).


2010 Technology Goals:
Hydrogen Transition
Hydrogen storage systems demonstrating an available capacity of 6 weight percent hydrogen, specific energy of 2000 W-h/kg, energy density of 1100 W-h/liter at a cost of $5/kWh.
Internal combustion engine powertrain systems operating on hydrogen with a cost target of $45/kW by 2010 and $30/kW in 2015, having a peak brake engine efficiency of 45%, and that meet or exceed emissions standards.
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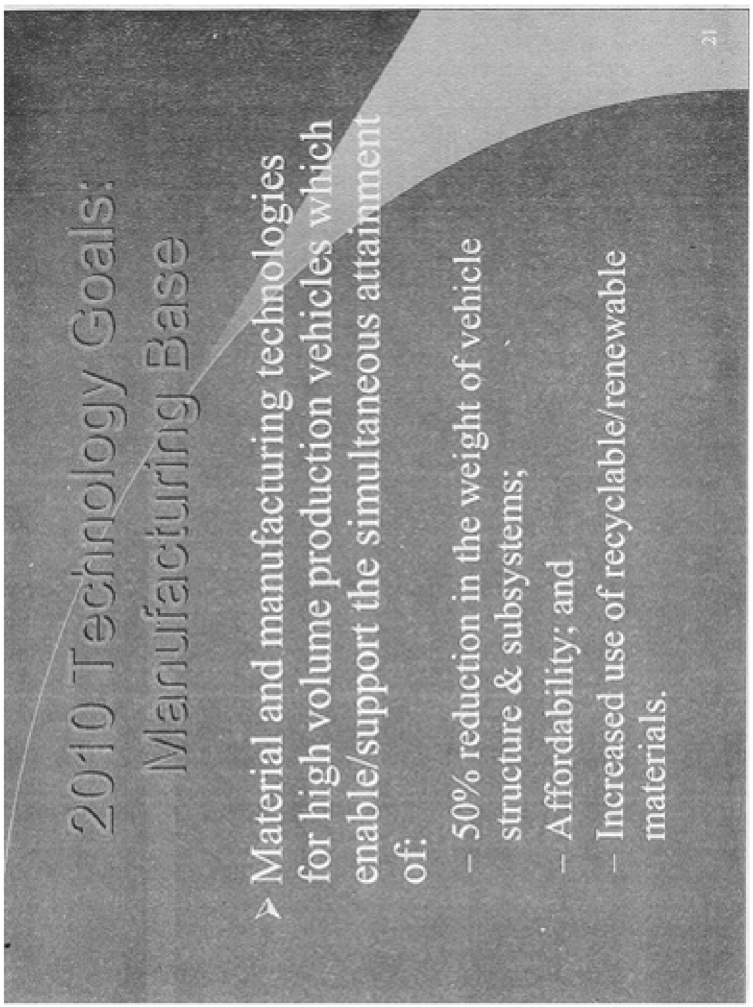
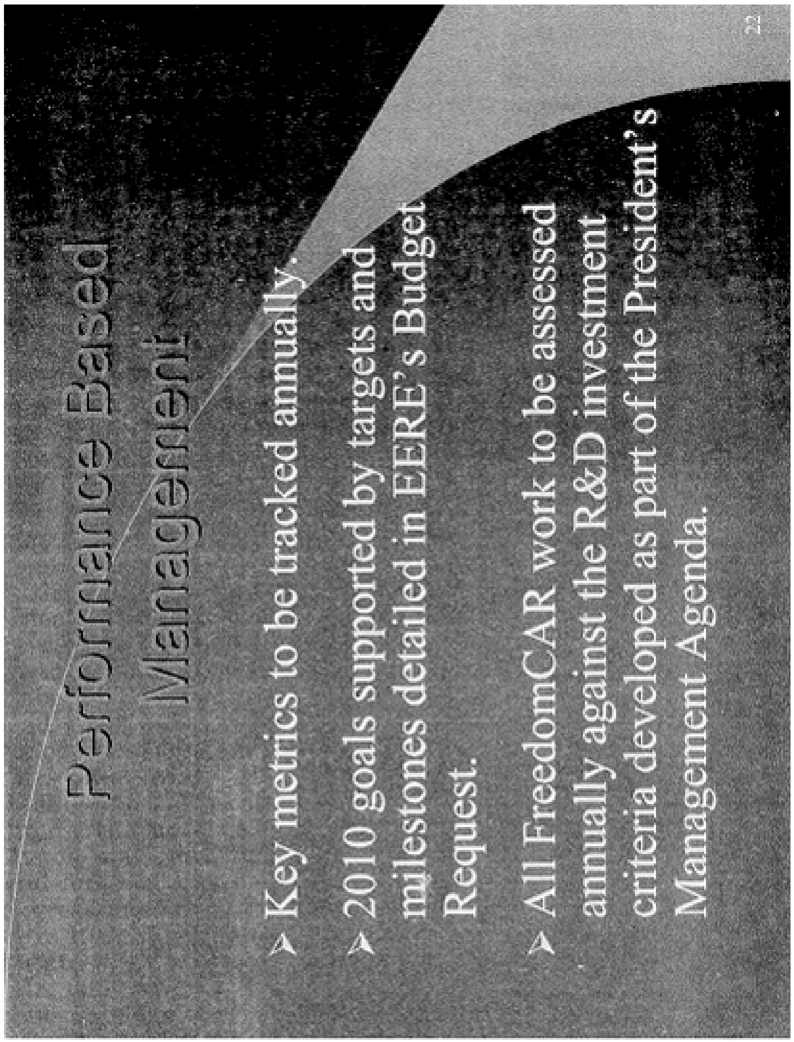
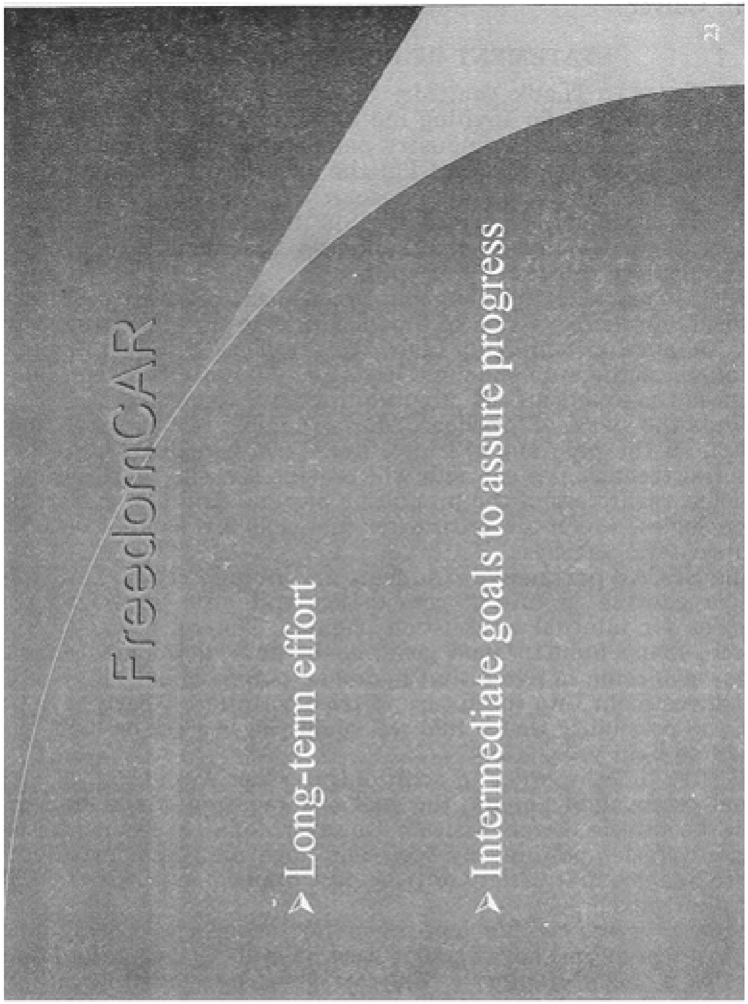

2010 Technology Goals:
Manufacturing Base
➢ Material and manufacturing technologies for high volume production vehicles which enable/support the simultaneous attainment of:
– 50% reduction in the weight of vehicle structure & subsystems;
– Affordability; and
– Increased use of recyclable/renewable materials.
21


Performance Based Management
➢ Key metrics to be tracked annually.
➢ 2010 goals supported by targets and milestones detailed in EERE's Budget Request.
➢ All FreedomCAR work to be assessed annually against the R&D investment criteria developed as part of the President's Management Agenda.
22


FreedomCAR
➤ Long-term effort
➤ Intermediate goals to assure progress
23

Mr. GREENWOOD. Thank you, Mr. Garman.

Mr. Culver.

STATEMENT OF ROBERT N. CULVER

Mr. CULVER. Thank you, Mr. Chairman. Members of the committee, thank you for inviting me to address the committee today on the new government industry partnership called FreedomCAR. My name is Bob Culver and I'm the executive director of United States Council for Automotive Research, or USCAR. USCAR is the umbrella organization formed in 1992 by Daimler-Chrysler, Ford Motor Company and General Motors to conduct collaborative precompetitive research.

USCAR partners fully support Department of Energy Secretary Spencer Abraham's vision of a personal transportation system free from reliance on petroleum fuels. We are pleased to join Secretary Abraham at the auto show in Detroit on January 9th when he announced the FreedomCAR program to pursue this goal.

While the vision of FreedomCAR partnership is long range, many aspects of the program will have near-term benefits. Light-weight material technologies can and will provide benefits for a variety of vehicles, regardless of the propulsion system. And power electronic technologies, which are critical for fuel cells are equally beneficial for near-term vehicles.

The USCAR partners also support continuing FreedomCAR funding to address promising combustion and after-treatment technologies for internal combustion engines. Through decades of research, many industry and government and environmentalist experts have come to agree that hydrogen powered fuel cells are our best investment into the future of transportation. Nearly a decade ago, the possibility that a fuel cell could power a car or light truck appeared light years away.

At that time, in order to achieve the power equivalent of an internal combustion engine, the fuel cell required would be larger than the vehicle it would power. However, today experimental passenger vehicles powered by fuel cells have been demonstrated by our companies in a variety of segments, from compact cars to SUVs and mini vans.

While progress on this very promising technology is being made, much research and development work is still needed. Affordability remains a major challenge. The cost associated with putting fuel cell power trains into vehicles at the current technology level are literally in the hundreds of thousands of dollars. Significant progress on this affordability challenge must be made in order to make a business case for producing them and marketing them.

Because this technology is high risk but offers significant societal benefits, it is appropriate and necessary for government. USCAR worked with the Department of Energy to streamline and refocus our partnership on longer term, higher reward technologies such as hydrogen powered fuel cells. As Secretary Abraham made clear, this is not a short-term vision. It will take many years of hard work by the auto industry, by energy providers and Federal research organizations to realize this bold vision. Industry and the DOE have agreed on detailed near-term technical goals for each research area. Mr. Garman just showed you those. And they are also attached to my testimony.

Along with technical road maps, the goals will ensure that funds are being spent in the most promising areas and that research is progressing. While the vision of a hydrogen-based transportation system is decades away, it is extremely important to begin addressing the issues involved with shifting the balance from petroleum and toward hydrogen. It is also critical to demonstrate user-friendly hydrogen fueling stations and to develop a road map for the new infrastructure development. FreedomCAR can serve to jointly develop those demonstration plans and milestones to lead the transition to hydrogen-powered vehicles.

FreedomCAR research is being focused at the component and subsystem level which will be applicable to a wide range of vehicle segments. This will facilitate the migration of technologies into the most appropriate vehicle platform as the technologies meet their goals. The auto industry pledges to bring these advanced technologies to market as soon as the business case can be made for them, while at the same time providing our customers with vehicles that are safe and give them the kinds of performance, function, utility and value they need and expect for their money. Past USCAR and government collaborative programs have provided, and will continue to provide, benefits to the American public. New material technologies have helped reduce weight and combustion and after treatment technologies are migrating to today's vehicles. Clean fuels including low sulfur diesel are a must if these interim technologies are going to make it into the marketplace.

All of the USCAR partners have announced hybrid electric vehicles in the 2003 and 2004 timeframe, and all in truck and light duty or SUV segments where this technology will yield the maximum fuel savings.

In summary, the USCAR partners are in full support of FreedomCAR and are hard at work at advanced technologies including technologies that will help make hydrogen powered vehicles a reality. Thank you.

[The prepared statement of Robert N. Culver follows:]

PREPARED STATEMENT OF ROBERT N. CULVER, EXECUTIVE DIRECTOR, UNITED SATES COUNCIL FOR AUTOMOTIVE RESEARCH

Mr. Chairman and Members of the Committee: Thank you for inviting me to address the committee on the new industry/government cooperative research partnership called FreedomCAR. My name is Bob Culver and I am the Executive Director of the United Sates Council for Automotive Research, or USCAR. USCAR is the umbrella organization founded in 1992 by DaimlerChrysler, Ford Motor Company, and General Motors to conduct collaborative, pre-competitive research.

The USCAR partners fully support Department of Energy Secretary Spencer Abraham's vision of a personal transportation system free from reliance on petroleum fuels. We were pleased to join Secretary Abraham at the North American International Auto Show on January 9 when he announced the FreedomCAR program to pursue this goal.

While the vision of the FreedomCAR partnership is long range, many aspects of the research will likely have nearer term benefits. Lightweight material technologies can and will provide benefits for a variety of vehicles regardless of propulsion system. And power electronic technologies, critical for fuel cell drivetrains, are equally beneficial for nearer-term vehicles. The USCAR partners also support continuing FreedomCAR funding to address promising combustion and aftertreatment technologies for internal combustion engines.

Through decades of research, many industry, government and environmentalist experts have come to agree that hydrogen-powered fuel cells are our best investment into the future of transportation. Merely a decade ago, the possibility that a fuel cell could power a car or light truck appeared to be light years away. At that time, in order to achieve the power equivalent of an internal combustion engine, the fuel cell required would be larger than the vehicle it would power. However, today experimental passenger vehicles, powered by fuel cells, have been demonstrated by our companies in a variety segments, from compact cars to SUVs and minivans.

While progress on this very promising technology is being made, much research and development works is still needed. Affordability remains a major challenge. The costs associated with putting fuel cell powertrains into vehicles at the current technology level are literally in the hundreds of thousands of dollars. Significant future progress on this affordability challenge must be made in order to make a business case for producing them. Because this technology is high risk but offers significant societal benefits, it is appropriate and necessary for Government involvement.

USCAR has worked with DOE to streamline and refocus our Partnership on longer term, higher reward technologies such as hydrogen-powered fuel cells. As Secretary Abraham has made clear, this is not a short-term vision—it will take many years of hard work by the auto industry, energy providers, and federal research organizations to realize this bold vision. Industry and the DOE have agreed on detailed near term technical goals for each research area, which are attached to this testimony. Along with technical roadmaps, the goals will ensure that funds are being spent in the most promising areas and that research is progressing.

While the vision of a hydrogen-based transportation system is decades away, it is extremely important to begin addressing the issues involved with shifting the balance from petroleum and toward hydrogen. It is also critical to demonstrate user-friendly hydrogen fueling stations and develop a roadmap for the new infrastructure development. FreedomCAR can serve to jointly develop demonstration plans and milestones to lead the transition to hydrogen powered vehicles.

FreedomCAR research is being focused at the component and sub-system level which will be applicable to a wide range of vehicle segments. This will facilitate the migration of technologies into the most appropriate vehicle platforms as the technologies meet their goals. The auto industry pledges to bring advanced technologies to market as soon as a business case can be made for them while at the same time providing our customers with vehicles that are safe and give them the kind of performance, function, utility, and value they need and expect for their money. Past USCAR and government collaborative programs have provided, and will continue to provide benefits to the American public. New materials technologies have helped reduce weight, and combustion and aftertreatment technologies are migrating to today's vehicles. Clean fuels including low sulfur diesel is a must if these interim technologies are going to make it into the market place. All of the USCAR partners have announced hybrid electric vehicles in 2003/2004 and all are in truck and SUV segments where this technology yields the maximum fuel savings.

In summary, the USCAR partners are in full support of FreedomCAR and are hard at work on advanced technologies, including technologies that will help make hydrogen powered vehicles a reality.

FreedomCAR: Energy Security for America's Transportation

[AGREEMENT BETWEEN DEPARTMENT OF ENERGY AND UNITED STATES COUNCIL FOR AUTOMOTIVE RESEARCH]

Vision: Affordable full function cars and trucks are free of foreign oil and harmful emissions, without sacrificing safety, freedom of mobility and freedom of vehicle choice.

Message: America's transportation freedoms:

- Freedom from petroleum dependence
- Freedom from pollutant emissions
- Freedom to choose the vehicle you want
- Freedom to drive where you want, when you want
- Freedom to obtain fuel affordably and conveniently

National Benefits: Ensure the Nation's transportation energy and environmental future, by preserving and sustaining America's transportation freedoms. In other words, Freedom and Security made available through Technology.

> The government and industry research partners recognize that the steady growth of imported oil to meet our demand for petroleum products is problematic and not sustainable for the Nation in the long term. No single effort limited to one economic sector can successfully change this trend. Altering our petro-

leum consumption patterns will require a multi-tiered approach, including policy and research programs, across every end use sector of our economy. The transportation sector has a significant role to play in addressing this challenge, and success resulting from the FreedomCAR research initiatives will help accomplish the broader National Goals and Objectives that are being pursued.

Strategic Approach:

- Develop technologies to enable mass production of affordable hydrogen-powered fuel cell vehicles and assure the hydrogen infrastructure to support them.
- Continue support for other technologies to dramatically reduce oil consumption and environmental impacts.
- Instead of single vehicle goals, develop technologies applicable across a wide range of passenger vehicles.

Technology Specific 2010 Goals [1]

- To ensure reliable systems for future fuel cell powertrains with costs comparable to conventional internal combustion engine/automatic transmission systems, the goals are:
  - Electric Propulsion System with a 15-year life capable of delivering at least 55kW for 18 seconds, and 30kW continuous at a system cost of $12/kW peak.
  - 60% peak energy-efficient, durable fuel cell power system (including hydrogen storage) that achieves a 325 W/kg power density and 220 W/L operating on hydrogen. Cost targets are at $45/kW by 2010 ($30/kW by 2015).[2]
- To enable clean, energy-efficient vehicles operating on clean, hydrocarbon-based fuels powered by either internal-combustion powertrains or fuel cells, the goals are:
  - Internal combustion engine powertrain systems costing $30/kW, having a peak brake engine efficiency of 45%, and that meet or exceed emissions standards.
  - Fuel cell systems, including a fuel reformer, having a peak brake engine efficiency of 45%, and that meet or exceed emissions standards with a cost target of $45/kW by 2010 and $30/kW in 2015.[2,3]
- To enable reliable hybrid electric vehicles that are durable and affordable, the goal is:
  - Electric drivetrain energy storage with 15-year life at 300 Wh with discharge power of 25 kW for 18 seconds and $20/kW.
- To enable the transition to a hydrogen economy, ensure widespread availability of hydrogen fuels, and retain the functional characteristics of current vehicles, the goals are:
  - Demonstrated hydrogen refueling with developed commercial codes and standards and diverse renewable and non-renewable energy sources. Targets: 70% energy efficiency well-to-pump; cost of energy from hydrogen equivalent to gasoline at market price, assumed to be $1.25 per gallon (2001 dollars).[4]
  - Hydrogen storage systems demonstrating an available capacity of 6 weight percent hydrogen, specific energy of 2000 W-h/kg, energy density of 1100 W-h/liter at a cost of $5/kWh.[5]
  - Internal combustion engine powertrain systems operating on hydrogen with a cost target of $45/kW by 2010 and $30/kW in 2015, having a peak brake engine efficiency of 45%, and that meet or exceed emissions standards.
- To improve the manufacturing base, the goal is:
  - Material and manufacturing technologies for high volume production vehicles which enable/support the simultaneous attainment of:
  - 50% reduction in the weight of vehicle structure & subsystems,
  - affordability, and
  - increased use of recyclable/renewable materials.

References

[1] Cost references based on CY 2001 dollar values. Where power (kW) targets are specified, those targets are to ensure that technology challenges that would occur in a range of light-duty vehicle types would have to be addressed.

[2] Does not include vehicle traction electronics.

[3] Includes fuel cell stack subsystem, fuel processor subsystem and auxiliaries; does not include fuel tank.

[4] Targets are for hydrogen dispensed to a vehicle assuming a reforming, compressing and dispensing system capable of dispensing 150 kilograms per day (assuming 60,000 SCF per day of NG is fed for reforming at the retail dispensing station) and servicing a fleet of 300 vehicles per day (assuming 0.5 kgs used in each vehicle per day). Targets are also based on several thousand stations, and possibly demonstrated on several hundred stations. Technologies may also include chemical hydrides such as sodium boro-hydride.

[5] Based on lower heating value of hydrogen; allows over 300-mile range.

Mr. GREENWOOD. Thank you, Mr. Culver. The opening statement of the gentleman from Michigan will be placed in the record. And we appreciate his presence.

The Chair recognizes himself for 5 minutes for questions.

To each of the members of the panel, I would ask this question. It is implicit in the fact that the Congress appropriates roughly $150 million annually for this program that we are investing in research that would otherwise not happen, not occur. I'm interested in understanding the premise for that assumption. The auto makers have spent a lot of money, I believe a billion dollars was spent on acquiring Ballard fuel systems—Ballard power systems—by Daimler-Chrysler and Ford collectively to acquire partial ownership in that company. So why do we think that without the investment of public dollars, this research would not go on at a pace in the private sector? We'll start with you, Mr. Culver.

Mr. CULVER. I'd like to try that one, Mr. Chairman. The investment in fuel cell manufacturers is a new investment for all the auto companies to ensure their place once the research goals of being able to make these affordably will be realized. I believe that there is still tremendous research needed to help reduce the cost, improve the durability, improve the efficiency of fuel cells before they can be ready for the marketplace. Combining the efforts of the auto industry, the supplier community, the national labs will help ensure that and accelerate that progress.

Mr. GREENWOOD. Mr. Wells, your views.

Mr. WELLS. I can relate to the work we did a couple of years ago when we were actually looking at the accountability and trying to track the contributions during the PNGV program. Clearly when we talked to the industry, we were made aware of a large dollar value of their committed R&D effort. I believe in that particular year it was, like, $18 billion by the major car companies in all kinds of R&D efforts. Their contribution self-acknowledged to the Federal agencies that were involved in the PNGV effort were in the neighborhood of $980 million, if I remember the numbers right, approximately 5 percent of their research they self-disclosed to us was being contributed toward related technologies for the PNGV vehicle.

Our point from a lessons-learned standpoint, as you design future efforts, to ensure that there are mechanisms available to ensure clear, crisp accountability and trackability for monitoring who's spending what and what the money is being spent for. So we would come at it from an accountability and a documentation standpoint.

Mr. GREENWOOD. Mr. Garman.

Mr. GARMAN. Yes, Mr. Chairman. It's difficult to expect auto makers to really invest their heart and soul and their dollars in technologies that aren't going to be ready for the showroom floor for 10 or 20 years, and I'll give you some examples. Hydrogen storage is a major problem to make the car have the kind of range it will need so that a consumer will want to buy it. One of the very long-term R&D efforts that the government is involved in that no auto maker is involved in are advanced storage technologies—such as carbon nanotubes—that have an affinity for the storage of hydrogen.

This is the kind of work that goes on at a place such as the National Renewable Energy Lab in Colorado, a government lab. But I wouldn't expect the auto makers to engage in that kind of high-risk long-term technology, because its promise for the showroom is so far off, that it's just not a good investment of their dollars. It's a very iffy proposition. So it's an appropriate role for the government to invest in long-term high-risk technologies, and that's part of the focus and the thrust behind FreedomCAR.

Mr. GREENWOOD. Well, personally, I would invest zero or ten times what we're investing if I thought it was going to—whatever approach would give us the results that you gentleman have referred to as quickly as possible. How do we know—how do we arrive at the appropriation figure that we have? We've got this assumption that the auto makers are interested in having and have a national interest in investing in future technology, that this may be sufficiently over the horizon, that this inducement or this additional public investment makes a difference, but how do we know—who determines or how do we get to the answer of the question, what is the appropriate level of Federal funding that gets us where we want to go the quickest?

Mr. GARMAN. The real purpose of the Federal funding is to leverage some of the public dollars into the private dollars and to attract auto makers into areas of R&D that they wouldn't do by themselves. Ultimately, of course, Congress decides how much is appropriated, and our proposal is to appropriate roughly $150 million toward these activities, but there's the leveraging effect. We bring to the table—the Federal Government brings to the table facilities at the national labs, talent at the national labs that the auto makers would not by themselves have access to, regardless of how much money they spent in some cases.

Mr. GREENWOOD. The time of the Chair has expired.

The Chair recognizes the gentleman from Michigan for 5 minutes, and would say in advance that after the gentleman from Michigan's inquiry, the committee will recess for this vote and then return.

Mr. DINGELL. Mr. Chairman, thank you for your courtesy and I commend you for the hearing. I thank you for inserting my statement into the record.

Mr. Culver, do you believe that in view of our interest in promoting clean-burn diesels for passenger use in the United States, that we should lower the sulfur content in the diesel sulfur rule now pending at EPA?

Mr. CULVER. Mr. Dingell, thank you for the question. The alliance has recommended in the past the—that sulfur content of diesel fuel be reduced to 5 PPM or near-zero fuel. Such a reduction will increase the efficiency, help improve the durability of after-treatment systems, and help reduce the cost of after-treatment systems.

Mr. DINGELL. In other words, you'll improve the reliability of your catalytic converter?

Mr. CULVER. Yes, sir. Every so often you have to purge your catalytic treatment, your particulate trap. The lower the sulfur reduces the number of times you have to do that, improving the durability, lowering the cost, and you use diesel fuel to do that. So if you don't have to do it as often, you actually improve——

Mr. DINGELL. Europeans are going to zero?

Mr. CULVER. That is correct.

Mr. DINGELL. And that will especially enable them to bring on the Audi A-2 system, will it not?

Mr. CULVER. I'm not familiar with the Audi A-2 system, but I know that——

Mr. DINGELL. They have a clean burn system in Europe, the Audi A-2, which will get them 78 miles a gallon for a four-passenger car. The hybrids and the fuel cell vehicles and so forth will get some 60 miles per gallon for a two-seater car, a much smaller vehicle. Is that not true?

Mr. CULVER. I'm not sure of the Audi system, sir, but I do know that——

Mr. DINGELL. Would you——

Mr. CULVER. Zero PPM sulfur will enable the full potential of diesel technology to be realized without compromises of after-treatments.

Mr. DINGELL. So is the feasibility of developing the technology to meet future sulfur emissions requirements greater with fuel that has a sulfur content of 5 to 10 parts per million rather than the 15 parts per million required by EPA's diesel sulfur fuel? I believe you said yes to that.

Mr. CULVER. Absolutely.

Mr. DINGELL. Now, it's been reported that EPA has had Toyota run emissions tests on clean burn diesel vehicles for the European market. The tests were conducted using diesel fuel with a sulfur content of 6 parts per million. The vehicle passed all but one of the emissions tests the EPA performed. The test that failed was conducted by running the vehicle for long periods of time at highway speeds, fully loaded and with air-conditioning on. Is it feasible for the U.S. motor industry to develop technology to make clean-burn diesel engines that comply with the emissions tests that the Toyota vehicle recently failed, or should we be thinking in terms of lowering the sulfur content even below 6 parts per million?

Mr. CULVER. Again, I'm not familiar with the technology that was on the Toyota vehicle, but I do agree that the durability and performance at 5 PPM or closer to zero PPM will improve the durability and enable us to meet the tests—meet all the tier 2 requirements much easier than with 15 PPM.

Mr. DINGELL. Now, the American auto industry currently makes clean burn diesel vehicles that are used throughout Europe. Is that not so?

Mr. CULVER. Yes, sir, it is. In fact——

Mr. DINGELL. And what percentage of the new light duty vehicle sales and new luxury vehicle sales are attributable to clean burn diesel vehicles in the European market?

Mr. CULVER. Currently, it's about 30 percent. There are reports that it will go as high as 50 percent as Europe tries to meet their CO_2 commitments.

Mr. DINGELL. Europe is going to zero on diesel fuel sulfur content; is that right?

Mr. CULVER. That is correct.

Mr. DINGELL. Now Mr. Garman, do you agree that the lower sulfur fuel like they have in the European Union is necessary for emissions technology to work effectively and durably over the life of a clean burn diesel vehicle?

Mr. GARMAN. Yes, sir, a lower sulfur standard in diesel is very desirable. I need to make one clarification, though. Currently the EU standard for on-road diesel is 350 parts per million. They're moving to a cap of 50 parts per million in 2005 and considering a lower cap for later years. Some of the European countries have a diesel fuel tax incentive in place to reward the use of 10 parts per million fuel in later years. They generally refer to the 10 part per million number as zero sulfur fuel even though it doesn't actually have zero, but it has very low amounts. The EPA standard—our current U.S. cap is 500 parts per million which is clearly not amenable to clean-burning diesel. We need to do a lot better than that, and the U.S. has established a cap of 15 parts per million for 2006.

Mr. DINGELL. Mr. Chairman, I know my time is up but I have just one more question if you'd bear with me.

Do you believe, Mr. Culver, that clean-burn diesel vehicles would be attractive to consumers in the U.S. market?

Mr. CULVER. Absolutely. We know that they would be very attractive.

Mr. DINGELL. Given effectively zero sulfur diesel fuel, do you believe the U.S. motor vehicle industry can build clean burn diesel vehicles that will satisfy EPA emission requirements at a price customers will be willing to pay?

Mr. CULVER. I do, and I believe that we'd also bring them in in markets where they provide the biggest benefit in vehicles like light trucks and SUVs and mini vans.

Mr. DINGELL. And we can do this at huge fuel savings, can we not?

Mr. CULVER. The projection of fuel savings range from 25 to 35 percent improvement over existing fuel economy.

Mr. DINGELL. Mr. Chairman, I thank you.

Mr. GREENWOOD. The Chair thanks the gentleman. The committee will stand in recess until approximately 10:30.

[Brief recess]

Mr. GREENWOOD. The committee will return to order. The Chair recognizes the gentleman, Mr. Stearns, for 5 minutes.

Mr. STEARNS. Good morning and thank you, Mr. Chairman. Before I start, I'd like to welcome Dr. Vernon Roan, professor of mechanical engineering and director of the Fuel Cell Laboratory at the University of Florida. He was kind enough to come up here and say hello to me.

On the new apportionment, Mr. Chairman, I might have, and the University of Florida returned to be within my Congressional district, and I look forward to that opportunity.

The first question I have is for Mr. Culver. I just have sort of a threshold question to start out. Is government needed in this research? Clearly the auto makers are pursuing fuel cell technology and other advanced automotive technology on their own, spending sums far greater than the Department of Energy is spending. So can you sort of elaborate on your role in the FreedomCAR partnership. What does the USCAR bring to the partnership considering the amount of money that they're doing and the amount that the private industry is doing, and perhaps, do we need government research on this when the private industry is doing it?

Mr. CULVER. Let me—thank you. Let me start by saying that the numbers Mr. Wells quoted earlier are directionally correct for the year that the GAO talked to us, but the far great majority of that money we spent on R&D is heavily related to the D side in developing products for the next generation of vehicles going into production within the next few years, and quite—and the pressure is to put more and more toward the near term and less and less on the long term as we get into especially tight years like we're in right now.

I do believe government research is necessary for many reasons. One, government scientists have shown that they are free from some of the constraints that the auto industry is, and when we can combine their expertise with our sense of the business case, we can really push the technology forward collaboratively, the leverage opportunities of all of us working together really actually make the sum total much greater than would be any one of us working alone. So I think the collaborative aspect is really important in this whole aspect.

And finally, I believe that the goals that we're working on for the FreedomCAR program all have costs and durability kinds of efforts in them, which is a little new to this program before the prior program. And it's important to do that, because if we have the costs and durability and customer into the equation now with the new program, we can help really ensure that these technologies will get to the marketplace faster.

The auto company is spending a lot of money on these technologies. With the government we're really accelerating the pace of bringing that to the marketplace.

Mr. STEARNS. I think it has been brought out in some of the opening statements is to get to the ultimate goal of the FreedomCAR of the hydrogen as a fuel, it's going to require a lot more expenditure for petroleum products, and can you talk a little bit about that tradeoff, we're going to have to spend a lot more, go import a lot more to even get us to the point where we have the feasibility or release of a fuel cell of hydrogen? I mean, it seems like it's a total impediment to get us to where we want to go, we're going to have to expend more petroleum to get it out of the ground, to store it and all that.

Mr. CULVER. I apologize. I'm not sure of the question. I know there are many—you're talking about the production of hydrogen?

Mr. STEARNS. Yeah. Just to get to the production of hydrogen, we're going to have to spend a lot of gasoline petroleum products to get there. Isn't that true?

Mr. CULVER. Well, there are many different scenarios being investigated for the production of hydrogen.

Mr. STEARNS. Let me ask Mr. Garman on that. Is that true?

Mr. GARMAN. Sure. I mean, we don't see market penetration of this technology for quite some time, so in the general course of events, we will be importing and using a lot of petroleum between now and then, and also——

Mr. STEARNS. But to get to the ultimate objective, we're going to spend even more petroleum than we would in a normal——

Mr. GARMAN. Not necessarily, because hydrogen can be produced from a variety of sources. It can be produced from natural gas. It can be produced from renewable energy, from biomass, from nuclear. There are a lot of options available to us in the short and long term to produce hydrogen from a variety of different sources, and that's one of its attractions.

Mr. STEARNS. Mr. Garman, what do you see as the greatest technological impediment to this program's success?

Mr. GARMAN. Fuel cell cost and durability. Right now fuel cells cost on the order—the designs we have today—of $400 to $450 per kilowatt. We're going to an internal combustion engine costs roughly $30 to $35 per kilowatt. We're going to have to decrease the cost of the fuel cell stack by an order of magnitude in order to make it competitive with internal combustion engines.

Right now the models we have operate an average of 3,000 hours. If you want to get something comparable to an automobile that will last 120 or 150,000 miles, we need a 5,000-hour fuel cell. So cost and durability of the fuel cell itself are fundamentally important technical challenges for us to overcome.

Mr. STEARNS. Mr. Chairman, this is my last question. This is for Mr. Garman. Again, you say in your testimony that, quote, neither industry nor government working alone is likely to overcome these barriers in any reasonable timeframe. Therefore, we must work in partnership. And I ask Mr. Culver a little bit about the government's need for research and so forth. So can you explain how this working together is—will speed up the process and perhaps elaborate on the government's role and the industry's role in this partnership and how that works.

Mr. GARMAN. Sure, and I'll probably do that the best way by giving you a real world example. The auto makers have been looking at fuel cells for many years and dismiss them as being just too expensive and saying it's going to take us a long time to bring down that cost. And actually there's work at Los Alamos National Laboratory by scientists there, working in partnership with the industry to actually say, how can we bring down the cost of fuel cells?

There's a membrane and a PEM fuel cell of the type we're talking about that uses a lot of platinum in that membrane to actually help the reaction happen, and the scientists at Los Alamos were able to reduce the amount of platinum needed in that membrane by a factor of 10, and thus they brought down the costs significantly.

I mentioned how expensive fuel cells were now in relation to where they needed to be to produce a commercial product, but I failed to mention the fact that—in the last 5 or 6 years—we've decreased the cost of fuel cells by an order of magnitude as well. So we've made great progress, and what we want to do is to continue that progress so that we get toward a commercial product.

Mr. STEARNS. That magnitude has come down 10 percent, 20 percent—what would you say the percent that that costs.

Mr. GARMAN. An order of magnitude of a 100 percent. I'm sorry, an order of magnitude of 1000 percent.

Mr. STEARNS. Thousand percent?

Mr. GARMAN. Yes.

Mr. STEARNS. Thank you, Mr. Chairman.

Mr. GREENWOOD. I thank the gentleman and recognize the gentleman from Florida, Mr. Deutsch, for 5 minutes.

Mr. DEUTSCH. Thank you. If each of you can respond to this question. How long will it take to develop fuel cell-powered vehicles for mass production in the United States? Mr. Culver.

Mr. CULVER. I believe mass production won't occur for at least a decade. We will be seeing fleets appear on the market, small volume fleets in the numbers of hundreds of vehicles within the next 2 to 3 years, but the cost—to get down to the costs that Mr. Garman just mentioned will take at least another decade in my opinion.

Mr. DEUTSCH. Mr. Wells.

Mr. WELLS. One of the first questions we asked, about the FreedomCAR, we were told that this is not a car. We've also heard DOE talk to a horizon 40, 50 years in terms of building component pieces and putting it all together.

Mr. DEUTSCH. Mr. Garman.

Mr. GARMAN. If we meet every one of the technology goals that we've specified over the next decade, the auto makers—we believe—will be in a position to make a decision about commercialization in the 2012 to 2015 timeframe, and that's a commercialization decision on mass production vehicles. As Mr. Culver indicated, we have a few tens of fuel cell vehicles on the road today that will migrate up to hundreds, then thousands, then 10,000's as we do demonstrations and start to work on aspects of infrastructure, but mass marketed hundreds of thousands of vehicles on the road we don't see until the 2015 to 2020 timeframe. And total fleet turnover would take much longer than that, and that's assuming that we're successful in addressing these first tranche of technological goals that we have for ourselves over the next decade.

Mr. DEUTSCH. So in your opinion in a best-case scenario, are you talking 2015 for a mass production?

Mr. GARMAN. Yes, sir.

Mr. DEUTSCH. And that's——

Mr. CULVER. In that case is with the—such that we have in place at that time an infrastructure that will support those vehicles, which is absolutely crucial.

Mr. DEUTSCH. Uh-huh. And what comes first?

Mr. CULVER. That's a great question. Constantly talking about the chicken and egg of whether you get fuel cells first or whether you get an infrastructure first and the way to really address that is to look at demonstrations and the Department of Energy's plan includes demonstrations that will have limited fleets expanding to wider fleets and more wide fleets and as the track develops around those fleets, it will be critical to expand it in many areas before commercialization is possible.

Mr. DEUTSCH. You were mentioning there how many fuel cell vehicles actually on the roads today in demonstrations?

Mr. GARMAN. We've through the California fuel cell partnership, SunLine transportation, Ballard has some—in Vancouver, Canada. Mostly on bus and fleet vehicles, in the tens, I would say.

Mr. CULVER. Probably not more than a hundred worldwide.

Mr. DEUTSCH. Worldwide?

Mr. CULVER. Right.

Mr. DEUTSCH. Okay. And outside of the United States, I mean, is anyone taking any kind of a role in any magnitude comparable to us?

Mr. CULVER. Europe has some programs going on, especially in Germany with some buses that are out at Munich Airport, for example. Japan is doing some work as well in fuel cell vehicles. We've had a chance to see one of those at the Future Car Congress earlier this week. So there is worldwide effort going on.

Mr. DEUTSCH. Is there any kind of coordination between these pure research efforts?

Mr. CULVER. Not on the fuel cell manufacturer level. There have been calls for development on how we approach infrastructure together. Secretary Abraham has talked about a conference to bring together the different markets to talk about these issues and——

Mr. DEUTSCH. Is there any reason why we shouldn't be coordinating with basically all of the industrialized world on this issue?

Mr. CULVER. Well, areas like the California fuel cell partnership also bring in the Japanese manufacturers and the European manufacturers as well. So some of that is happening at that level. It's a little tougher to collaborate worldwide on a day-to-day basis like we do with the Department of Energy, but I think those efforts are increasing.

Mr. DEUTSCH. Why is it more difficult?

Mr. CULVER. Just face-to-face collaboration, working together in the same laboratory side by side with researchers. And that's what FreedomCAR really helps us do, get those people together.

Mr. DEUTSCH. You know, one of the comments people were saying that the development of fuel cell-powered vehicles for mass production is around the corner over 30 years ago. What has changed to make this goal more realistic today?

Mr. CULVER. I believe the progress in the last decade. As Mr. Garman pointed out, we've already reduced the fuel cell price a tenth by—down to a tenth of what it was a decade ago. Size of the fuel cells, as I mentioned, were so huge, you had to tow them in a trailer 15 years ago. Now they're in A class vehicles. So I think that progress has really excited us about moving that much closer to marketplace than we were 20 years ago.

Thank you. I see my time has expired.

Mr. GILLMOR. Thank you very much, Mr. Chairman. And let me ask Mr. Garman: You state in your testimony that you are beginning to address the technologies necessary to make a transition to a hydrogen-based transportation economy. Several of the witnesses highlight in their testimony the need to address infrastructure issues. What is the timeframe for addressing hydrogen infrastructure development, and what are FreedomCAR's plans on this front?

Mr. GARMAN. It is very important that we develop infrastructure in a timeframe that makes it possible, about the same time that the automakers are making that commercial ization decision in the 2013 to 2015 timeframe. Before we start investing heavily in infrastructure, it is important that we continue to see over the next year or 2 or 3 that we are meeting these very difficult technical challenges, the cost and durability goals and fuel cells, so that we are assuring ourselves that we do have something that we would be building an infrastructure for ultimately. But I think we are in the process of putting together our 1904 budget and, planning in a 5-year planning timeframe, for budgets in the 1904 to 1909 time-frame, are thinking very hard about this infrastructure problem and how government will work in this area.

Some of the areas that we need to work on include codes and standards, how hydrogen would be handled, how it would be stored. This is a government role. We also want to employ the convening power of government to bring energy companies into the mix. Companies such as BP, Texaco, Shell, and others are thinking themselves not exclusively as oil companies anymore, but energy companies, and they as well have to think about how they might want to provide this service to consumers when the time is right.

So, part of the technical milestones as outlined in the testimony are geared specifically and directly toward the cost of hydrogen and the ability to produce it in an affordable manner and distribute it appropriately.

Mr. GILLMOR. Are you working with companies that may, in the future, be providing some of that infrastructure; for example, oil companies, pipeline companies?

Mr. GARMAN. Yes, sir. We have involved them in some of our hydrogen technology road-mapping exercises, companies such as Air Products and Chemicals, Prax Air. There is—they have a substantial amount of hydrogen pipelines and production in play today, and it's roughly a $2 billion industry, if memory serves.

Mr. GILLMOR. When we are talking about energy security issues, you mentioned that hydrogen is very plentiful as a resource to produce for the fuel cell car. But given that the hydrogen must be produced, how is FreedomCAR and DOE addressing the fuel supply issues?

Mr. GARMAN. We, in a variety of ways, through DOE's fossil energy program, we are looking at ways, for instance, to use coal. Where coal would be gasified, the carbon dioxide and sulfur could be sequestered, and the pure hydrogen put into use. Through the nuclear energy program, we are also looking at the possibility of high-temperature gas reactors being used over the very long term to produce hydrogen. We are also looking at hydrogen conversion technologies, using biomass and, of course, renewable—other renewable technologies such as wind and solar.

We have a variety of different ways to produce hydrogen. The one that's used mostly today is natural gas, the steam reformation from natural gas. Natural gas is very rich in hydrogen, and that's how it's mainly done today.

Mr. GILLMOR. Let me ask you to elaborate a little more on what's being done and what the potential is in the coal area. And I have a somewhat parochial interest in asking that since Ohio is the Saudi Arabia of coal with a 600-year supply that we can't use. So I would be interested in how far we are coming and what you realistically think the potential might be in that respect.

Mr. GARMAN. Yes. Absolutely. I mean, the United States is blessed with a bountiful and abundant coal resource, and coal is chemically nothing more than long strings of hydrogens and carbons with some sulfurs and a few other elements mixed in. If we can use coal gasification technology, which we have been working on at DOE for some years, and marry that up with sequestration, that that could separate the rich hydrogen gas from the coal gas, capture the other elements, and sequester them in perhaps the mine from which the coal came through a chemical or other type of process, then we would have coal, the use of coal that would be consistent with a carbon-free future. And this is something that is very important to us.

Again, this is a long-term technology. We don't see this happening in an economic fashion any time soon, but in the next 15-, 20-year timeframe, we hope that we can have some demonstrations of this technology well in hand.

Mr. GILLMOR. Thank you.

Mr. GREENWOOD. The next gentleman, and recognizes himself, for 5 minutes for this next round of questions.

There has been some concern as to whether the FreedomCAR program, with its bold vision of leaping forward into fuel cells, is going to in any way diminish our efforts with regard to the intermediate steps, trying to get the hybrid vehicles on line and available to the public.

Mr. Culver, what are your views on that? Are we, in fact, in any way, by focusing some of these resources on the fuel cells, diminishing our progress in the other hybrid vehicles?

Mr. CULVER. Well, I trust not, sir, Because about 50 percent of the budget that was proposed, the FreedomCAR budget, goes toward—directly toward hydrogen and fuel cell technologies. The other 50 percent goes to nearer-term technologies, like lightweight materials, advanced combustion, batteries, those types of technologies, which, for the most part, will be required and are very supportive of the longer-range fuel cell goals.

I think it's very important, and the U.S. Car Partners have provided input to the Appropriations Committee that those technologies be preserved in the budget and still get the adequate funding. There are promising technologies under way investigating on reducing after-treatment—or reducing emissions through advanced after-treatment technologies. New materials like magnesium and advanced composite materials are slowly coming into the realm of being available for nearer-term vehicles.

So these types of technologies, we believe, are crucial and critical and should be retained in the FreedomCAR program.

Mr. GREENWOOD. Let me ask you, on that question, and I would like Mr. Garman to respond and perhaps Mr. Wells as well, what are the incentives to get, to make, to reach milestones by particular timeframes? In other words, if a group of scientists in a research lab in the private sector—clearly there are corporate goals, and they, I imagine, devote a certain amount of attention trying to figure out how to reach those milestones in a timely fashion. I mean, there is a sense that—particularly because of our concern with the war on terrorism and our desire to be free of foreign oil, freer of foreign oil—that we have an almost Manhattan Project approach to getting these vehicles on line. Is that—is there a sense of urgency? And what determines the pace, what drives the pace of our getting to these hybrid cars, and how do we in Congress judge whether we are making the progress in a timely enough fashion?

Mr. CULVER. I believe there are many parts to the answer to that question. Let me begin by saying the ultimate answer is that they get into the marketplace. In the next 2 years, you will see hybrid offerings from all the Big Three in trucks, SUVs. Customers are starting to show greater appreciation for fuel economy as a discriminator amongst various models, and the companies recognize that being able to offer higher-fuel-economy vehicles are certainly going to be in the marketplace and be more attractive. So I think the customer side, the pull of these technologies is starting to come into play much more than it was even a few years ago. So I think that will help bring it to marketplace a lot faster.

Mr. GREENWOOD. I'm not sure that that's responsive to my question. My question, if we were simply relying on the pull of the marketplace, we wouldn't need Federal dollars, because the car—automakers would accelerate their efforts to beat—to get marketable vehicles on the market faster than the other companies. So if we are going to infuse $75 million a year into accelerating this advancement, my question is, what makes the guys in the laboratories scurry across the room faster and, you know, work their brains quicker and collaborate more efficiently using these Federal dollars?

Mr. CULVER. I do believe the new goals, with timing and cost in all of the new goals, will help accelerate that progress and help get that sense of urgency across to everyone involved in this program.

Mr. GREENWOOD. Let me ask Mr. Wells and Mr. Garman to also respond to that question.

Mr. WELLS. Mr. Chairman, as they design this program, the Congress should insist that measurable points in time be identified so that you can measure success.

Mr. GREENWOOD. And is it your view that those milestones are now absent?

Mr. WELLS. I believe those milestones are not—I'm not able to interpret those milestones yet because they are fairly technical, and it's difficult at this moment to really measure the concreteness of those measurements. But clearly we have moved into a society where performance and results will get future funding in terms of the scarce dollars we have. So the program is going to have to be held accountable to demonstrate results quickly to get continued funding.

Mr. GREENWOOD. Mr. Garman.

Mr. GARMAN. I would agree. And one of the reasons that we had technical milestones is that our own Office of Management and Budget insisted that we did and will be measuring our budget requests and our performance against those technical milestones on a year-by-year basis. This is a very, very important thing.

I also—I think there is a certain excitement in this partnership between the government project managers, and the private sector scientists and the government scientists in the lab who are working on this process, because we developed these milestones together. In the past there have been some so-called partnerships where the government said this is our goal, this is our milestone, and, frankly, the private sector participants weren't full participants in the process of setting these milestones. But they are invested in these milestones. They would come up with—they came up with them in partnership with us, and they are excited but challenged by the milestones, and, like any engineer or any lab, you know, you get excited by a good challenge. These are tough challenges.

I would also, with respect to your question about hybrids, which are very important, I think it's very important to recognize what the Congress has done in response to the President's energy plan in putting forth tax credit opportunities for hybrid vehicles. We think this is very important and commend the Congress for doing that. We think this is going to be an important incentive for customers who are teetering on the edge of buying a hybrid to be able to do it. I have one hybrid vehicle, and I am looking forward to the time when I get to purchase another one from a U.S. auto manufacturer, and, frankly, the tax credit is helpful in that regard.

Mr. GREENWOOD. A final question. What are the proprietary issues? How are they managed in terms of U.S. automakers, foreign automakers? Is it—how are we balancing out the normal commercial interests or proprietary knowledge against the societal urgency of getting where we want to go here? Who wants to take a stab at that? Mr. Garman?

Mr. GARMAN. I see this first-hand when you go to, for instance, Oak Ridge National Laboratory. We have a power electronics lab where lab scientists and industry scientists will work side by side on a workbench on a technology. But we also have space in that lab for proprietary technology in which the private sector worker will go behind the curtain, if you will, and try to carry it further or make it distinctive in some way for their own commercial interest.

We think this is kind of a healthy dichotomy of approaching these kinds of R&D challenges. They work together on one hand, but they have an opportunity to take the technology and take it a step further and commercialize it perhaps sooner than their competitors can. And we try to maintain that balance.

Mr. CULVER. I would agree.

Another good example is the California fuel cell partnership, where all the companies are collaborating together to demonstrate refueling, demonstrate the safety, demonstrate the drivability of these vehicles. Yet, at night, those vehicles go into very secure individual garages, and we don't share any of that kind of information, so there is room for proprietariness and collaboration to coexist at the same time.

Mr. GREENWOOD. Thank you, gentlemen, for your testimony, and we appreciate your help here this morning, and you are excused.

And the Chair would call forward the second panel, consisting of Dr. Vernon Roan, professor of mechanical engineering, and director of the Fuel Cell Laboratory at the University of Florida; Mr. William Miller, president of UTC Fuel Cells; and Dr. Donald Paul, vice president and chief technology officer of Chevron-Texaco.

Doctor, I think we would like you to sit at that chair.

Welcome, gentlemen. We thank you for your assistance this morning. You heard me notify the first panel that this is an investigative hearing, and it is our practice to take testimony under oath. Do any of you object to giving your testimony under oath?

Seeing no such objection, I would advise you that, pursuant to the rules of the House and this committee, that you are entitled to be advised by counsel during your testimony. Do any of you wish to be advised by counsel?

Okay. In that case, if you would rise and raise your right hand, I will swear you in.

[Witnesses sworn.]

Mr. GREENWOOD. Thank you. You are under oath. And I understand I should stand corrected; it's Dr. Vernon P. Roan, not Run. We thank you, and you are recognized to give your testimony, sir.

TESTIMONY OF VERNON P. ROAN, PROFESSOR OF MECHANICAL ENGINEERING, DIRECTOR, FUEL CELL LABORATORY, UNIVERSITY OF FLORIDA, ON BEHALF OF THE PNGV PEER REVIEW COMMITTEE, NATIONAL RESEARCH COUNCIL; WILLIAM T. MILLER, PRESIDENT, UTC FUEL CELLS, SOUTH WINDSOR, CONNECTICUT; AND DONALD L. PAUL, VICE PRESIDENT AND CHIEF TECHNOLOGY OFFICER, CHEVRONTEXACO

Mr. ROAN. Thank you, sir. Thank you for inviting me here today. I would like to start by just giving a few comments from the summary of the Peer Review Committee, who oversaw the PNGV program, and I will just go right into that. Since I have issued a written copy of all this, I'm only going to hit just a few of the points because I have a few additional comments I would like to make.

Of the goals, goal 3 is the one that has received the most attention, and that's to try to develop the fuel-efficient car, family sedan, up to 80 miles per gallon. In terms of the—some of the comments and recommendations from the Peer Review Committee, the first bullet, the Committee believes that the PNGV program has established a unique and valuable framework for directing closely coordinated industry and government research efforts toward the development of technologies capable of solving societal problems.

That's probably the most important bullet from the recommendations of the committee and the comments, because basically we see this government industry framework as having worked.

The fourth bullet down: Fuel cells continue to show promise of high efficiency and very low emissions, with continuous progress toward targets that are very difficult to meet for any general-purpose, high-volume automotive application.

And, as such, the next to the last bullet, from the inception of PNGV, practical automotive fuel cell power plants have been considered to be well beyond the 2004 time limit of the program.

And the next one, basically we said that we should extend those targets.

If I go to the next sheet, a couple of recommendations. Essentially the first bullet says that the PNGV program should be refined and redefined to better reflect current societal needs, and the ability of the cooperative program, so forth, to meet these needs.

The second bullet: Because of the potential for near zero tailpipe emissions and high-energy efficiency of the fuel cell, the PNGV should continue the research and development efforts on fuel cells even though achievement of performance and cost targets simultaneously will have to be extended substantially beyond the original expectations.

So what these issues say is that the Peer Review Committee felt that the PNGV approach worked. We felt that the fuel cell was one of the most attractive technologies, and that should be considered on a longer-term basis, and, essentially, that's what the FreedomCAR program does.

I would like to skip the next slide, if I may, and go to the next one.

Hydrogen production issues. And this comes to a little of what Congressman Stearns was asking about a moment ago. Right now almost all of our hydrogen is produced from natural gas. We get about a 70 or 75 percent energy efficiency in doing that, and actually a little lower when we take into account compressing and transferring the hydrogen to where it's used. So it takes about 4 pounds of natural gas to produce a pound of hydrogen, roughly.

When we use renewable energy sources, you have to consider the question: Do you do better making hydrogen, or do you do better by using that renewable energy to retire some of the fossil-burning coal plants which are still operating at 25 or 30 percent efficiency?

The next slide, please.

As Mr. Garman mentioned, there are other ways than steam reforming hydrocarbons or the electrolysis of water to produce hydrogen, but none of these have really been shown to be successful yet. It is also possible to sequester the CO_2. That's still an unknown. The electricity can be produced in a lot of ways, but if we use fossil fuel to make electricity, and if we use fossil fuel—namely, natural gas—to make hydrogen, we wind up actually putting more CO_2 into the air than we are doing right now.

In terms of the magnitude of this—the next slide, please, the effect of electrolysis. To produce hydrogen for an 80-mile-per-gallon fuel cell car would take about 600 kilowatt hours per month of electricity from using electrolysis of water. For a two-car family, assuming they drive a little less than the average combined, this would be about 1,000 kilowatt hours per month, and that's about what the average home actually uses right now.

So, regardless of where we get this electricity, including from renewable, we are essentially going to have to duplicate the entire grid insofar as electrical energy is concerned if we are going to produce enough hydrogen for all of the cars.

I won't go into the next ones, I'm out of time——

Mr. GREENWOOD. Dr. Roan, don't worry about the time.

Mr. ROAN. Yes, sir.

Mr. GREENWOOD. Don't worry about the time.

Mr. ROAN. Continue?

Mr. GREENWOOD. Please do.

Mr. ROAN. Okay. The next slide on the transportation issues is basically the fuel for hydrogen transportation.

The next one, please. No, the previous one.

This shows what we can do with basically 1 pound of natural gas. Right now, if we use this in a conventional car, which we can and we do, this would take us about 4.3 miles. If we put this in a 60-mile-per-gallon hybrid, which we can, this would take us about 9.6 miles. If we put it into a fossil-fuel fuel cell car, which hasn't really been demonstrated, but we projected about 70 miles per gallon, this pound of natural gas would take you about 11 miles.

If we use natural gas to make hydrogen, that same pound of natural gas now would take us about 2.6 miles in a present car, about 5.8 in a hybrid, and about 7.5 in a hydrogen fuel cell car, which is going to be more efficient than the hydrocarbon fuel cell car.

I don't think that we would have any problem with 80-mile-per-gallon on that.

The next slide basically shows what we are doing from the standpoint of carbon dioxide in the atmosphere, And these are very approximate numbers, because, obviously, they depend on the assumptions that you make.

But if we use our petroleum fuel directly, on the left side I have the amount of energy, of petroleum-based energy, that's required. This is to travel 300 miles. Using a present car would take about 1.4 million BTUs of petroleum energy. That produces around 240 pounds of carbon dioxide. If we go to a 60-mile-per gallon hybrid, that brings that down to about 630,000 and about 107 pounds of carbon dioxide. If we go to a hydrocarbon fuel cell—and, again, the 70-miles-per-hour—70-miles-per-gallon would still have to be demonstrated—we are down to about 540,000 BTUs and 95. It actually, in terms of the best utilization, probably right now would be a diesel compression ignition, CIDI, hybrid, which would give probably about 80 miles per gallon. So this gives us the lowest consumption of petroleum and the least amount of CO_2 produced.

If we go to hydrogen produced from steam-reformed natural gas, the amount of energy now, because we are losing energy in producing hydrogen, is up to about 2.1 million BTUs; and, if we use it in a conventional car—which we can—and that produces about 270 pounds of CO_2. In a spark ignition hybrid, that would bring it down to 950,000, and 125; and the hydrogen fuel cell down to about 710,000 and about 95 pounds of CO_2.

And, finally, if we use hydrogen from electrolysis, older fossil plants—now, this is not from renewable, this is using our current electricity supply to produce hydrogen—then we have the worst in terms of the CO_2 and the BTUs. Even if we use hydrogen fuel cell, it's a lot of energy, and it's a lot of CO_2. In other words, using current electricity is not the way to produce hydrogen.

The bottom line on that—the next slide—as we move toward this hydrogen economy, we will probably use more fossil fuel and produce more greenhouse emissions per capita than we do right now; and this is likely to continue until there is a big reduction in fossil fuel power plants. We either have to go to renewable or nuclear. And even after we transition, the total energy—not fossil energy, but total energy consumption is probably going to increase unless we change our energy use patterns, because it takes more energy to make the hydrogen that we are using for our transportation systems.

And, finally, I support the concept of the FreedomCAR program. I think this is a long-term thing, and I think we really need to be working on it. And I think that what the government can do, especially with the support of the national labs, that's going to be of great benefit in eventually getting there.

So the production and distribution of hydrogen, the storage of hydrogen onboard vehicles. Just, very quickly, right now, if you took the size of a gasoline tank and used it to store compressed hydrogen, it would hold about 2 pounds of hydrogen, roughly, and that would take you less than 100 miles. So we have to have some way to store the hydrogen onboard the vehicles.

And, of course, the fuel cells themselves, they have to be made, the price right, durable, safe, and so forth.

Thank you, sir.

[Material submitted by Vernon P. Roan follows:]

A BRIEF SUMMARY OF RELEVANT FINDINGS AND COMMENTS FROM THE NRC PNGV PEER REVIEW COMMITTEE 7TH REPORT

Submitted to: House of Representatives Committee on Energy and Commerce

Submitted by: Vernon P. Roan, Vice Chairman PNGV Peer Review Committee National Research Council

FreedomCAR Hearings June 6, 2002

The following is a brief summary of some of the Peer Review Committee comments and findings felt to be relevant to the Committee on Energy and Commerce FreedomCar hearings.

The Partnership for a New Generation of Vehicles (PNGV) was initiated on September 29, 1993, as a cooperative research and development (R&D) program between the federal government and the United States Council for Automotive Research (USCAR). The PNGV goals and basis for National Research Council (NRC) reviews, in summary, are:

Goal 1. Significantly improve national competitiveness in manufacturing for future generations of vehicles.

Goal 2. Implement commercially viable innovations from ongoing research on conventional vehicles.

Goal 3. Develop vehicles to achieve up to three times the fuel efficiency of comparable 1994 family sedans. (This goal implies up to 80 mpg.)

The PNGV declaration of intent requires an independent peer review "to comment on the technologies selected for research and the progress made."

The review and reports focused on assessments of: 1) the overall balance and adequacy of the research program to meet the technical goals; and, 2) efforts to develop commercially feasible low emission propulsion systems.

Goals 1 and 2 are qualitative in nature but Goal 3, in addition to the technical targets, included time milestones calling for the development of concept vehicles by the year 2000 and production prototype cars by 2004.

The Seventh Report, "Review of the Research Program of the Partnership for a New Generation of Vehicles," presents the latest findings and recommendations by the review committee. It is impractical to summarize all relevant findings from the report since to do so would essentially require reproducing the entire report. Therefore, the following material represents a brief summary, including a few excerpts from findings and recommendations, felt to be pertinent for the issues being currently considered.

- The committee believes that the PNGV program has established a unique and a valuable framework for directing closely coordinated industry and government research efforts towards the development of technologies capable of solving important societal problems.

- The year 2000 concept-vehicle milestone (for Goal 3) was met when the three manufacturers each introduced concept cars: the Daimler-Chrysler ESX3, the Ford Prodigy, and the General Motors Precept. All three vehicles incorporated hybrid-electric power trains designed around small, turbocharged, compression-ignition, direct-injection (CIDI) engines, using diesel fuel. All three employed significant technical advances (reduced mass, improved aerodynamics, reduced auxiliary loads) developed in the PNGV program.

- The committee believes that no reasonable amount of funding would ensure achievement of all aspects of Goal 3, including 80 mpg (and cost), and that has been clear for some time. Breakthrough ideas and talented people are more stringent constraints than money in achieving this goal.

- The CIDI engine operating on diesel fuel continues to be the major focus of PNGV power plant development for near term application. Current PNGV activity centers on the challenge of meeting new emission standards and is being pursued in engine combustion, exhaust-gas after treatment, and fuels development programs.

- Fuel cells continue to show promise of high efficiency and very low emissions with continuous progress towards targets that are very difficult to meet for any general-purpose, high-volume automotive application.

- The PNGV concept vehicles made public (in the year 2000) made extensive use of lightweight materials and new body construction techniques to achieve major reductions (20 to 31 percent) in curb weight. The high cost of these lightweight materials and the associated manufacturing costs represent a significant part of the affordability challenge faced by the program.

- High prospective cost is a serious problem in almost very area of the PNGV program.

- As noted earlier, affordability is the linchpin of the PNGV program. For the benefits PNGV intended to be realized, the economics must favor large-scale purchases of these vehicles.

- From the inception of PNGV, practical automotive fuel cell power plants have been considered to be well beyond the 2004 time limit of the program. Nevertheless, because of their potential for high-energy efficiency and no onboard emissions of any regulated pollutants when using hydrogen as a fuel, the development of these systems has remained a major part of PNGV.

- The original targets for the year 2000 for the fuel cell systems were not met—the dates for meeting these targets should be extended substantially. Size and weight need to be reduced by at least a factor of two (to meet 2004 targets) and (projected) cost is roughly six times the target value (for 2004 PNGV-type vehicles).

- The need to reduce fuel consumption and carbon dioxide emissions of the U. S. automotive fleet is more urgent than ever. Since 1993 (when the PNGV was formulated) there has been a 20% increase in the petroleum used in highway transportation, the percentage of U. S. petroleum from imports has risen to 52 percent ...

- ... during this time (since 1993) the demand for SUVs, vans, and pickup trucks in the USA has drastically increased now make up 46 percent of new light-duty vehicle sales (note, it was recently announced that for the past year they exceeded 50 percent).

- .In view of these facts and as a new energy policy is being developed for the nation, it is the committees belief that priorities and specific goals of the PNGV program should be reexamined.

- Recommendation. Taking into account the successes, degree of progress, and lessons learned in the PNGV program to date, government and industry participants should refine the PNGV charter and goals to better reflect current societal needs and the ability of a cooperative, precompetitive R&D program to address these needs successfully.

- Recommendation. The PNGV should continue the aggressive pursuit and development of lean-combustion, exhaust-gas after-treatment systems.

- Recommendation. Because of the potential for near-zero tailpipe emissions and high- energy efficiency of the fuel cell, the PNGV should continue research and development efforts on fuel cells even though achievement of performance and cost targets (simultaneously) will have to be extended substantially beyond original expectations.

- .Recommendation. Because affordability is a key requirement the committee believes that more attention should be paid to the design and manufacturing techniques being worked up by the American Iron and Steel Institute in the Ultralight Steel Auto Body Advanced Vehicle Concept Project.

- . Recommendation. High priority should be given to determining what fuel sulfur level will permit the preferred compression-ignition direct-injection (CIDI) engine and its after-treatment system to meet all regulatory and warranty requirements.

- The power train with the highest probability of meeting the vehicle fuel-economy target of 80 mpg by 2004 is the hybrid-electric power train powered by a CIDI engine. (It was pointed out, however, that the EPA tier 2 emission standards for NOx and particulates promulgated in 1999 brought into question the possibility of meeting these new requirements in a CIDI production prototype engine by 2004).

- From all the evidence the committee has seen during past reviews, the cost premium of a PNGV-type vehicle with a fuel economy close to 80 mpg will likely be several thousand dollars more than a competing conventional vehicle.

- In the committee's view, the PNGV program has been a success largely because:

  1. It set a deadline for a specific, focused, measurable stretch goal that was publicly visible, judged to be important by the government, and could motivate substantial industry support.

  2. It required cooperation between industry and government organizations working on pre-competitive R&D projects – and it established an organizational structure that involved these key potential contributors in a truly collaborative manner.

  3. It resulted in better use of the national laboratories and their tremendous resources to help resolve many of the very difficult issues.

- The committee indicated that it believed that future activity could benefit from:

1. A clear statement of the societal need being addressed ...

2. Funding from the government at an overall level appropriate to the potential societal payoff ...

3. Continuation of the program beyond 2004.

4. Deadlines appropriate for the tasks of major projects ...

5. Construction of a series of concept vehicles and a review at agreed-on dates of technologies developed ...

6. Creation of a high-level forum among the partners to discuss tradeoffs ...

7. Emphasis on fundamental R&D for high risk, high payoff technologies.

Other Related Questions and Answers

The following questions are felt to be of potential interest to the Committee on Energy and Commerce FreedomCAR hearings. The questions and responses were not addressed specifically by the PNGV Peer Review Committee and represent my own personal opinions and views.

1. What were the advantages and disadvantages of PNGV having an explicit goal of a deliverable product integrating a variety of technologies, i.e., a mid-size sedan that would get up to 80 miles per gallon? Regardless of whether the particular goal of PNGV was appropriate, how important is it that government-industry partnerships have a concrete, integrated deliverable product as a goal?

I believe that in the early stages of the PNGV, there were big advantages to having such an explicit goal. This approach allowed quantification of potential energy-efficiency benefits associated with:

- mass reduction
- aerodynamic improvements
- auxiliary load (heating, A/C, power steering, etc.) reduction
- power plant energy conversion efficiency
- system configuration and optimization
- on-board energy storage systems

It also allowed approximate "sizing" of major components for many vehicle configurations and system options with a result that all technology developers were working towards common goals. This was especially important in the beginning when focus and consistency helped the newly-formed government/industry teams become viable operating groups.

The major disadvantages, in my opinion, were:

- The targeted "family" car was a very price-competitive vehicle with good fuel mileage (~27 mpg) and several generations of evolution to reduce mass and otherwise increase fuel efficiency. Thus, it was a very difficult "target" vehicle.

- Now (as at the beginning of PNGV) fuel expense represents a relatively small fraction of the cost of owning a family car and, as such, there is little incentive for a buyer to choose fuel economy as a high-priority item.

- In some ways, the fixation on 80 mpg detracted attention from the original primary objectives of reducing U.S. petroleum consumption and reducing CO_2 emissions.

- Due to the shift in car sales away from family sedans and towards SUVs and light trucks, more petroleum could be saved with a smaller fuel efficiency increase if these larger vehicles were targeted.

All things considered, however, I believe that the original Goal 3 was a reasonable and proper approach, especially at the time the program was initiated.

I think that it is now less important that the government-industry partnerships have a concrete, integrated deliverable product as a goal than it was at the beginning of PNGV. However, I still believe that the best way to achieve consistency and to minimize confusion during technology development is to have a common focus.

2. Did PNGV focus too much on shorter-range research on technologies that were already in reach? If so, what areas of research were neglected? What is the appropriate balance between shorter-term and longer-term in the research portfolio of a government-industry partnership?

I think that very little of government-supported research focused on technologies that were already in reach. On the other hand, with the exception of the fuel cell, most technologies perceived to be significantly beyond the 1994 timeline were not retained in the active program.

While I don't know of any areas of research that were totally neglected, there are some which might justify more priority on the basis of a longer-term approach, such as:

A) Direct methanol fuel cells.

B) Unconventional onboard energy storage devices.

C) Alternative membrane materials for PEM fuel cells (higher temperature, lower cost).

D) Additional means of lowering costs for manufacturing using higher-strength steel, aluminum, and composite materials.

E) A more detailed investigation of fuels, issues, especially the production, infrastructure and vehicle onboard storage of hydrogen.

In my opinion, the appropriate balance between shorter-term and longer-term research in this context, is that priority should be given to research that has clear societal benefits but would not likely be successfully pursued by industry alone. For the most part, I believe that this translates into a combination of higher risk and/or longer-term research. I hesitate to put numbers on the distribution since it must be put in context but, typically, I think that more than half of the effort should be for the longer-term activities.

3. What areas of research should the government focus on to move toward a hydrogen-based transportation system? To what extent did PNGV focus on those areas? Is it more important for the government to invest in areas related to vehicles, or in areas related to the distribution system and other ancillary areas that could stall a shift to fuel cells?

There are three major areas of fuel availability-related (as opposed to fuel utilization-related) research areas to move towards hydrogen-based transportation:

A) Hydrogen production. Currently, essentially all hydrogen is produced from stream-reforming of natural gas. Further, this is an endothermic process resulting in the heating value of hydrogen obtained being less than that of the feedstock natural gas. Additional energy is required for compression or liquification as well as for transportation. For large-scale hydrogen production, a large new supply of natural gas or other primary feedstock would be needed if present production techniques are to be used.

The dissociation of water to produce hydrogen utilizes an almost unlimited supply of feedstock, but the electrical energy required to produce a unit of hydrogen is at least double that of the electrical energy which would be produced by consuming that unit of hydrogen in a fuel cell. Consequently, innovative and inexpensive primary energy sources such as renewables or, perhaps, nuclear will have to be exploited to produce the hydrogen. Even with acceptable primary energy sources, the total power requirements and production facilities to replace even a fraction of current petroleum energy, are staggering.

B) Infrastructure. For hydrogen-powered vehicles to be commercially viable, fuel must be readily available to the consumer, nationwide. There are currently, perhaps, around 200,000 refueling stations for gasoline. These refueling stations accommodate vehicles which have ranges in excess of 300 miles and can be refueled in minutes by persons with no expertise or training. Thus, it is likely that at least tens of thousands (perhaps many more) refueling sites for hydrogen, distributed all around the United States, will be needed to support large-scale production and sale of hydrogen-powered vehicles. Since there is currently virtually no infrastructure to provide this capability, clearly some innovative infrastructure approaches are necessary.

C) Vehicle refueling and on-board storage of hydrogen. The energy density of hydrogen (energy stored per unit of storage volume) is much less than for gasoline or other alternative fuels. For example, to store on-board, the same energy available from the typical 16-gallon gasoline tank would require about a 200-gallon volume for compressed (5000 psi) hydrogen gas or about 60 gallons for liquid hydrogen (at –423°F.). Even if the on-board energy efficiency is assumed to be doubled (for a non-hybrid system) or tripled (for a hybrid system), the resulting volume of about 70 gallons for compressed hydrogen would likely present a severe challenge to vehicle designers. The use of liquid hydrogen would ease the storage volume problem, but producing liquid hydrogen is very energy intensive, and handling it at –423°F. presents obvious safety problems.

Materials such as metal hydrides or carbon fibers offer the potential for reducing hydrogen storage problems, but the design of practical systems with clear advantages over pressurized hydrogen are thus far elusive. Clearly, some highly innovative approaches to improve the practicality of hydrogen from both refueling and on-board storage standpoints will be essential to the ultimate success of hydrogen-fueled vehicles.

PNGV did include some efforts in all of the areas mentioned above. However, the time scale for a hydrogen-based transportation system was (and is) felt to be far beyond the 2004 milestone and even beyond the recommended extended milestone (~2008) for the PNGV fuel cell activities. It was felt that within these time frames, hydrogen-fueled, fuel cell vehicles would likely be produced in small numbers and limited to fleet or otherwise carefully controlled operations (including maintenance and refueling) and would have limited range (less than 100 miles). As such, most of the PNGV efforts were directed towards technologies felt to be within the PNGV timeframes and applicable to the target vehicle.

I believe that it is important for the government to be active in all three of the research focus areas mentioned since each will likely require highly innovative approaches for realistic solutions. Further, there must be satisfactory approaches within the same timeframe for all three major issues if the hydrogen-fueled consumer vehicle is to be a reality.

Of the three issues, those related to the refueling and on-board storage will probably require the most new technology developments and should, therefore,probably be given the largest share of government resources. New hydrogen-absorbing materials, higher-strength tank structural materials, conformable container concepts, better and/or less expensive approaches to compressing hydrogen, new leak detection devices, possible hydrogen odorants, automated refueling techniques, and many potential problem areas need much study and much innovation to reach satisfactory solutions.

The issues of appropriate feedstocks, production energy sources, centralized versus local production facilities, etc., will require comprehensive overall system studies with great emphasis on economics to determine the most practical approaches to providing massive amounts of transportation hydrogen.

Providing hydrogen distribution throughout the United States while meeting all local/state/federal licensing/safety/environmental requirements will also require many studies, also emphasizing economics. Central versus localized production, pipelines versus tank trucks (or other transportation), liquid versus gaseous versus absorption material for on-site hydrogen storage, etc., are all major issues which must be dealt with in resolving infrastructure issues.

The government, especially by utilizing some of the impressive resources at the national laboratories can and, in my opinion, should help resolve many of these critical issues.

ADDITIONAL COMMENTS BY VERNON P. ROAN, PROFESSOR, UNIVERSITY OF FLORIDA

These comments are presented as an addendum to the brief summary of relevant issues from the NRC 7th PNGV Peer Review Report that I have submitted to the Committee. I also refer the Committee to the complete report for additional information. This addendum is not based on any type of consensus from the PNGV Peer Review Committee but represents my own observations and opinions.

Since no specific questions have been presented to me by the Committee on Energy and Commerce, I will offer opinions which I think relate to the probable areas of consideration by the Committee, namely:

1. The appropriateness of emphasis on hydrogen and fuel cells for transportation-related energy visions of the future.
2. The viability of the proposed FreedomCAR program as an approach for directing government-sponsored research and development in support of long-range transportation energy goals.

With respect to the first area of consideration, the ultimate transition from fossil fuels to hydrogen as the primary chemical fuel is essentially inevitable. Fossil fuels represent a finite resource which will become increasingly more difficult and expensive to utilize. Further, it seems likely that other technologies competing for limited fossil fuel supplies (especially petroleum) such as for textiles, plastics, medicines, etc., might achieve a higher priority than simply burning the fuel to produce heat. Hydrogen, on the other hand, can be produced without consuming fossil fuels through the electrolysis of water by using non-fossil primary energy to produce the electricity. The non-fossil primary energy sources include hydro, wind, solar, geothermal, tidal, and nuclear.

The downside of producing hydrogen through the electrolysis of water is that more electrical energy goes into producing the hydrogen than will be available from the hydrogen fuel. This fact emphasizes the importance of utilizing the hydrogen in the most efficient manner as a transportation fuel. The most efficient manner currently known is to use the hydrogen in a fuel cell-powered vehicle. It should be noted, however, that while electricity is still being produced for the national power grid using some fossil fuel power plants, it might conserve more fossil fuel and produce fewer greenhouse gases to put the renewable energy-produced power into the grid and take older power plants off-line. Another potentially more efficient alternative could be to use the renewable-energy-produced power to recharge batteries in electric vehicles.

An interesting and troubling likely outcome of the transition period where a significant portion of the electricity to produce hydrogen might come from fossil-fuel plants and/or where hydrogen is partially produced from steam-reforming natural gas (as almost all hydrogen is produced today) is that the consumption of fossil fuel per unit of fuel energy available for transportation will likely increase. In other words, there will probably be a period of time when we actually use more fossil fuel in our efforts to transition from fossil fuels to hydrogen in transportation systems. In addition, since hydrogen must be produced in an energy loss process, the total electrical energy consumption as we move towards a hydrogen economy is sure to increase dramatically. For example, an average American home uses around 1000 kWh of electricity per month. If this home has two fuel cell cars operating on hydrogen, it will take about an additional 1000 kWh of electricity to produce the hydrogen fuel for the cars. The implication is that a complete transition to electrolysis-produced hydrogen for transportation fuel will roughly require doubling the residential electrical generation capacity.

Thus, the DOE vision of proceeding towards a hydrogen economy with fuel cells becoming the preferred way to utilize the hydrogen for transportation certainly seems appropriate but there will be troubling events along the way.

The second area of consideration involves the path and some of the related priorities en route to the long-range vision. The path and priorities are extremely important since, even under the best of circumstances, there will likely be some very difficult issues. Fossil fuels, which have been essentially free except for the costs of extracting and processing them, will be replaced with hydrogen which must be "produced.'" Millions of megawatts of new, non-fossil, power generation plants will be needed to replace older fossil fuel plants and to provide electrical power to produce the hydrogen. This transition will take decades and will involve huge amounts of capital expenditures. During this lengthy transition period, it will become increasingly important to have an orderly evolution of technologies which can contribute to more fuel-efficient vehicles. It will also be important to use the available fossil fuels in the most appropriate manner. As an example of the appropriate use of fuels, consider natural gas.

Natural gas is the cleanest burning and has the highest mass heating value of any fossil fuel currently being consumed. It is the primary heat source for many electrical power plants including virtually all now under construction or in the planning stages. It is also used as a motor fuel in spark ignition, compression ignition (diesel), and gas turbine engines. In addition, it is the feedstock for many chemical processes including virtually all of the hydrogen currently being produced. Each of these uses of natural gas is related to transportation energy options. Specifically, some of the ways that natural gas could be utilized for transportation, are:

1. Directly as a motor fuel for conventional cars.
2. Directly as a motor fuel for spark ignition (SI) or compression ignition (CI) hybrid vehicles.
3. Directly as a fuel for hydrocarbon fuel cell-powered vehicles (utilizing onboard fuel processors).
4. Directly as a power plant fuel to produce electricity for recharging electric vehicle batteries.
5. Indirectly as a feedstock to produce transportation hydrogen fuel through steam reforming.
6. Indirectly as an electricity generation power plant fuel to produce electricity which would then be used to produce transportation hydrogen fuel through electrolysis of water.

Adding to the complexity is the fact that the hydrogen produced by methods 5 or 6 could also be used in many ways for transportation purposes, including as a fuel for conventional vehicles, hybrid vehicles, or fuel cell vehicles. Interestingly, for the relatively near term, probably the most energy-efficient way to utilize the natural gas for transportation is directly as a fuel in CI hybrid vehicles. The least energy-efficient option is to use it to produce hydrogen by electrolysis and then to use the hydrogen in conventional vehicles. The successful development of enabling hydrocarbon fuel, fuel cell technologies could provide not only another energy-efficient alternative but also an alternative with extremely low emissions. However, once the hydrogen is produced (by any means), the most energy-efficient way to utilize it will be in hydrogen fuel cells.

Similar options obviously exist also for the most effective ways to utilize petroleum or any other form of fossil fuel. The options which are actually feasible will depend on many factors but certainly including the successes in developing many enabling technologies. Clearly, of high importance in technology development must be included the following:

1. Exhaust emission reduction at the source or through after-treatment for fuel-efficient compression ignition (diesel) engines.
2. The fuel processing and other issues associated with hydrocarbon fuel cell systems that would have costs, performance, physical characteristics, durability, etc., compatible with consumer cars and other transportation systems.

3. Clean and energy-efficient ways of producing hydrogen.
4. A plan for developing a hydrogen infrastructure that would be compatible with widespread distribution and use of hydrogen-powered vehicles.
5. Development of vehicle onboard hydrogen storage that will allow safe and inexpensive onboard storage of sufficient hydrogen to provide an adequate vehicle range.
6. The resolution of costs, performance, and other issues to make the hydrogen fuel cell truly a technology compatible with mass-produced, low cost automotive applications.

As a final note, it should be emphasized that even with a good plan for achieving large-scale hydrogen production and infrastructure, it will be exceedingly difficult and expensive to implement. As an example, an Argonne National Laboratory study (ANL/ESD/TM-140) concluded that capital costs for production facilities capable of producing 1.6 millions of barrels of gasoline-equivalent hydrogen fuel per day, could be $400 billion for production and $175 billion for distribution. Their study was based on a "high" market penetration of hydrogen-fueled vehicles by the year 2030. Another study by Directed Technologies, Inc. (DE-ACO2-94CE50389, July 1997) was more optimistic but was partially based on assumptions of unlimited availability of very inexpensive natural gas and unlimited availability of off-peak electricity at 1.5 cents per kWh. There are also the inevitable problems with siting and licensing of facilities, as well as the obvious safety concerns of distributing massive quantities of liquid (-423(F.) or high pressure (3000 to 5000 psi) hydrogen.

There are, of course, many other issues to be considered including many that should be fostered by the government en route to the long-term vision of a hydrogen economy and an efficient transportation utilization of the hydrogen. However, it is felt that the ones mentioned above are among the more important.

In summary, with respect to the proposed FreedomCAR plan, it appears that it is reasonably well considered and includes the necessary elements to guide and support the more critical technology developments in a fashion appropriate for the government. Since the duration will involve many years of activities and many potential pitfalls, progress should be reviewed regularly and programs and plans changed as deemed appropriate.

Freedom Car: Hurdles, Benchmark for Progress and Role in Energy Policy

Hearings

A Statement of

Vernon P. Roan, Ph.D., P.E.
Vice Chairman of the PNGV
PEER Review Committee
National Research Council

Professor of Mechanical Engineering,
Director of the Fuel Cell Laboratory
University of Florida

before the
Committee on Energy and Commerce
U. S. House of Representatives
June 6, 2002

Hydrogen Production Issues

- Little free hydrogen is available so hydrogen must be "produced"

  - Currently from Methane (natural gas) – steam reforming
    $CH_4 + 2H_20 + Heat + Catalyst$
    $\rightarrow 4H_2 + CO_2$ (Ideal)

- Current processes produce about 70 to 75% as much hydrogen energy as natural gas input energy. Even less when compression (or liquification) and transportation are included.

- Approximately four pounds of natural gas (~ 85,000 BTU) needed to produce one pound of H_2 (51,500 BTU) ready for vehicle refueling.

- Using renewable energy sources to produce electricity to produce hydrogen would not be as effective as putting the energy into the power grid to reduce fossil fuel consumption.

  - Each kwh of renewable energy put into the grid could displace over ½ pound of natural gas, nearly one pound of petroleum or nearly three pounds of coal being burned in power plants (~12,000 to 15,000 BTU).

  - That same kwh of energy would produce less than 1/10 pound of H_2 (~5,000 BTU)

through electrolysis
of water.

Hydrogen Production Issues – continued

- The same four pounds of natural gas could produce and transmit about 26,000 BTU (about 7.5 kwh) of electricity through the grid in the typical fossil fuel power plant (efficiency ~ 30%) or nearly double this amount in newer combined cycle power plants.

- Using electrolysis of water to produce hydrogen, the electricity produced from the four pounds of natural gas would produce about ½ pound of H_2 from older plants or nearly one pound from combined cycle plants. Additional energy would be required to compress (or liquify) the H_2 and transport it.

- Using natural gas to produce electricity to produce hydrogen is not energy effective.

Fuel/Hydrogen/Transportation Issues

- One pound of natural gas could provide energy to power an automobile
  - about 4.3 miles for present car (27 mpg)
  - about 9.6 miles for an advanced hybrid car (60 mpg)
  - about 11 miles (projected) for a fossil fuel fuel cell car (70 mpg)
- If the natural gas is steam-reformed to produce hydrogen,
  - about 2.6 miles in present car
  - about 5.8 miles in advanced hybrid car
  - about 7.5 miles in a hydrogen fuel cell car (80 mpg)

Hydrogen Energy/Greenhouse Gas Issue

- Producing hydrogen from fossil fuels results in a net loss in available energy, while still producing CO_2.
- Producing hydrogen from electricity produced from fossil fuels results in a much larger loss in available energy, and even greater production of CO_2.
- Producing hydrogen from renewable sources could (at present) save much more fossil fuel energy if the power was put into the grid.

Bottom Line

As we move towards a "hydrogen economy" we will probably use more fossil fuel (and produce more greenhouse emissions) per capita than at present and this trend will continue until there is a significant reduction in fossil fuel power plants.

Even after transitioning towards renewable energy sources, the total energy consumption per capita will likely increase – probably significantly unless energy use patterns change. This will be manifested primarily in a much greater capacity for producing electrical energy.

Longer Term Issues

- As fossil fuel becomes more scarce (and expensive), hydrogen produced from renewable or surplus energy becomes the most likely transportation fuel.
- Hydrogen fuel cell power systems will provide the most efficient utilization of hydrogen for transportation.
- Hydrogen fuel cell vehicles will produce zero emissions and zero greenhouse gases (excluding hydrogen production).
- On-board storage of hydrogen is a major range problem, but is less of a problem with fuel cell vehicles due to higher efficiency.
- At 3000 psi, a hydrogen fuel tank about the size of current gasoline tanks would hold about two pounds of hydrogen.

- Two pounds of hydrogen could provide a range of
  - about 30 miles in a conventional vehicle
  - about 60 miles in a hybrid vehicle
  - near 100 miles in a fuel cell vehicle

Major Research and Development Needs

- Production and distribution of hydrogen
  - main issues are cost, safety, and greenhouse gases
- On-board vehicle hydrogen storage
  - main issues are cost, safety, space requirements
- Hydrogen fuel cell power systems for consumer cars
  - main issues are cost, safety, performance, size, and durability

Effect of Electrolysis – Produced Hydrogen on Electrical Power Generation

- To produce hydrogen for a fuel cell car (80 mpg) will require about 600 kwh per month using electrolysis of water.
- For a two-car family the additional electrical power load would be over 1000 kwh per month.
- The average home currently uses around 1000 kwh per month of electricity.
- Converting to hydrogen-fueled vehicles (even high-mileage fuel cell vehicles) will roughly require doubling the present residential power grid capacity.

Hydrogen Production

- There are potential methods other than steam-reforming hydrocarbons or the electrolysis of water to produce hydrogen but none have yet proved practical.
- It is possible to sequester the CO_2 when producing hydrogen from hydrocarbon fuels but the practicality is not yet known.
- Electricity for the electrolysis of water can be produced by many means including solar, wind, hydro, nuclear, etc. However, it may conserve more fuel energy and produce less CO_2 to put this form of power into the grid and take older fossil fuel power plants offline.
- High-temperature combined cycle fuel cells provide other efficient alternatives to produce electricity from hydrocarbon fuels.

Hydrogen as a Fuel

Hydrogen is the cleanest fuel and has the highest energy per unit mass of any fuel considered for transportation, but-

- It requires more energy input to produce than will be available from the hydrogen.
- It yields greenhouse gases (CO_2) when produced from a hydrocarbon feedstock or when produced by electrolysis using a hydrocarbon fuel-based electricity.
- It is more difficult (and expensive) to transport and to store due to its low density.

En Route to a Hydrogen Economy

Most energy efficient and least greenhouse gases

- use petroleum-based or natural gas fuel directly in CIDI Hybrid or Hydrocarbon Fuel Cell

Least energy efficient and most greenhouse gases

- produce hydrogen by electrolysis of water-older fossil fuel plants and use hydrogen in conventional SI vehicles.

Approximate Fuel Energy Used and CO_2 Produced to Travel 300 Miles

I. Using petroleum-based fuel directly

A. Present-day car (27 mpg)
   1.4 million BTU fuel energy - 240 pounds of CO_2

B. Hybrid (SI) (60 mpg)
   630,000 - 107 pounds

C. Hydrocarbon Fuel Cell (70 mpg)
   540,000 BTU - 95 pounds

D. Hybrid (CI) (80 mpg)
   470,000 BTU - 82 pounds

II. Using hydrogen from steam-reformed natural gas

- A. Present-day car (27 mpg)
  - 2.1 million BTU fuel energy - 270 pounds of CO_2
- B. Hybrid (SI) 60 mpg)
  - 950,000 BTU - 125 pounds
- C. Hydrogen Fuel Cell (80 mpg)
  - 710,000 BTU - 95 pounds

III. Using hydrogen from electrolysis-older fossil fuel power plants-natural gas

- A. Present-day car (27 mpg)
  - 2.6 million BTU fuel energy - 340 pounds CO_2
- B. Hydrogen Fuel Cell Vehicle (80 mpg)
  - 900,000 BTU - 120 pounds

Mr. GREENWOOD. Thank you, Dr. Roan.

Mr. Miller?

TESTIMONY OF WILLIAM T. MILLER

Mr. MILLER. Thank you, Mr. Chairman. I am Bill Miller of UTC Fuel Cells, a subsidiary of United Technologies Corporation. I appreciate the opportunity to testify regarding DOE's FreedomCAR program and the role it plays in our national energy policy.

UTC Fuel Cells has been developing and producing fuel cells for more than four decades. With NASA, we have supplied the fuel cells for every U.S. manned space mission since the 1960's, including Apollo and today's space shuttle orbiter. Since 1991, we have produced a 200-kilowatt fuel cell for buildings called the PC25, and we have delivered 250 of these—is that better? Delivered more than 250 of these to customers in 19 countries on 5 continents.

Building on this extensive experience, we are now developing new fuel cell technology, the PEM technology, for transportation, commercial buildings, and residential.

UTC Fuel Cells is working with DOE and a number of car and bus manufacturers. These include BMW, Hyundai, Nissan, and Renault for auto applications, and ThoranAirs Bus for bus applications.

My written testimony is more detailed, but I would like to highlight several key points today.

UTC Fuel Cells participated in the PNGV program. As a leading developer of fuel cells, I can tell you that PNGV was a success because it served as a catalyst for fuel cell technology. Let me give you an example.

In our case, this public-private partnership led to the development of on a PEM fuel cell system that operates at ambient pressure and, consequently, is 20 percent more fuel-efficient than other PEM fuel cell technology, which relies on a compressor.

In addition, we developed the first gasoline-powered fuel cell system powerful enough to operate an automobile. This technology would allow us to use the existing gasoline infrastructure if it takes longer to develop the hydrogen infrastructure than we were expecting.

Today's FreedomCAR initiative builds on PNGV successes, but it faces hurdles. On the technical side, we must still reduce the system's cost, size, and weight while improving its durability and performance. We also need to address manufacturing processes and materials issues. Continued investment in core fuel cell power plant technology from both the private and public sources is needed to reach these goals, and the same joint effort is needed in the areas of hydrogen production, storage, and distribution that are key to establishing the hydrogen infrastructure that we are talking about.

PNGV drew on expertise from 19 national labs and 400 organizations in 38 States, and we urge that FreedomCAR continue the successful approach by incorporating and promoting significant involvement from fuel cell power plant makers and the entire supplier base to fuel cells. Every State represented on this committee has a fuel-cell-related supplier or natural gas interest that can benefit from fuel cell commercialization. But let me be clear. Although petroleum-free, emission-free transportation is a revolutionary concept, like most technologies, it will require an evolutionary process.

The introduction of stationary fuel cell power plants using PEM is the key starting point. UTC Fuel Cells plans to introduce new stationary fuel cells by the end of next year that will cost $1,500 to $2,000 per kilowatt in volumes of a few hundred, but they will be competitive in producing electricity in high-electricity areas like California and New York. This will be followed by the introduction of fuel cells for buses, starting with inner-city buses, and demonstrations in the 2004-2005 timeframe, with commercial availability in 2006 or 2007.

Automotive applications are the most demanding in terms of cost, weight, and size. Hence, it is understandable to take longer for fuel cells to successfully compete in this market. We are targeting $50 per kilowatt for the personal vehicle application by the end of the decade, as volume gets into the hundreds of thousands and millions of vehicles. In fact, we think the introduction will happen by 2010. As we gain experience and build volume by deploying fuel cells for stationary markets and then buses and then trucks and fleet vehicles, these successes can pave the way for the zero emission personal vehicle.

In summary, UTC Fuel Cells believes the FreedomCAR initiative is appropriately focused on hydrogen-fuel-cell-powered vehicles as a key element of a comprehensive long-term national strategy that will enhance energy security and deliver environmental benefits, and we look forward to partnering with DOE to achieve our common goal of an emission-free cycle of energy.

Thank you for the opportunity to testify, and I would be happy to answer your questions.

[The prepared statement of William T. Miller follows:]

PREPARED STATEMENT OF WILLIAM T. MILLER, PRESIDENT, UTC FUEL CELLS

Thank you Mr. Chairman. I'm Bill Miller, president of UTC Fuel Cells (UTCFC). I appreciate the opportunity to testify regarding the Department of Energy's (DOE) FreedomCAR program and the role it plays in national energy policy.

UTC Fuel Cells (UTCFC) is a unit of United Technologies Corporation, which is a $28 billion global manufacturer of Pratt & Whitney aircraft engines, Carrier air conditioners, Otis elevators and escalators, Hamilton Sundstrand aerospace systems and Sikorsky helicopters.

UTCFC'S FUEL CELL EXPERIENCE

UTC Fuel Cells has more than four decades of fuel cell experience. We've developed and produced the fuel cells for every U.S. manned space mission since the Apollo missions in the 1960s and continuing today with the Space Shuttle program. These fuel cells produce the electricity for the orbiter when it is in space and all the drinking water for the astronauts.

We've also sold more than 250 stationary fuel cell power plants to customers in 19 countries on five continents. Our installed base of these 200 kW fuel cell power plants, known as the PC25™, has accumulated more than five million hours of operating experience. The PC25 provides powers for schools, hospitals, military installations, data processing centers and other facilities in diverse operating conditions and customer configurations.

Building on this extensive experience, we are now developing new fuel cell technology for transportation, commercial and residential applications. UTCFC is working with DOE and a number of car and bus manufacturers to develop fuel cell power plants and auxiliary power units for vehicles. Our partners include BMW, Hyundai, Nissan and Renault for auto applications as well as United Parcel Service, Thor and Irisbus in the heavy-duty vehicle market.

For example, our hydrogen fuel cells now power four Hyundai Santa Fe Sport Utility Vehicles (SUVs). These cars are the world's first zero emission SUVs and get the gasoline equivalent of 50 to 60 miles per gallon. We are a member of the California Fuel Cell Partnership that is demonstrating fuel cell vehicle technology, including the Santa Fe, in real world operating conditions.

FUEL CELLS AND PNGV

Fuel cell R&D was funded under the Partnership for a New Generation of Vehicles (PNGV) effort during the early years of the program. Hundreds of technologies were evaluated prior to a 1997 "down select" of promising technologies that included: hybrid electric vehicle drive, direct injection engines, fuel cells and lightweight materials.

From UTCFC's perspective, PNGV was a success. It served as a catalyst for fuel cell technology, including UTCFC efforts with the Ford Motor Company that kicked off our entry into Proton Exchange Membrane (PEM) fuel cells for transportation applications.

We had two dramatic technology breakthroughs as a result of this cost shared program.

First, in cooperation with DOE, we developed a PEM fuel cell that operates at ambient or room pressure. Why is this important? This enables our system to achieve substantially better fuel economy than other automotive fuel cell systems.

Our system does not need a compressor, which can consume large amounts of power and decrease overall system efficiency. This ambient pressure technology enabled us to win "best in class" honors in two key performance tests at the Michelin Bibendum in California last year where new automotive technologies are evaluated by independent judges. This breakthrough would not have been possible without cost-shared PNGV funding.

Our second significant accomplishment under PNGV was the development of the first gasoline powered fuel cell system powerful enough to operate an automobile. This technology provides an alternative to automakers should the hydrogen infrastructure take longer than expected to develop by allowing us to use the existing gasoline infrastructure.

UTCFC's distinction is that its power plant can use readily available, pump grade gasoline. Other systems rely on specialized de-sulfurized fuel to accomplish this feat. UTCFC's success in this area is the result of leveraging its own resources, the resources and other expertise available through our United Technologies Research Center, as well as funding from the Department of Energy.

FREEDOMCAR/FUEL CELL HURDLES

Today's FreedomCAR initiative faces hurdles, not the least of which is a sustained national commitment and adequate levels of investment by the private and public sector. Other FreedomCAR challenges include technical, market, infrastructure and public policy hurdles before fuel cell vehicles are commercially available and DOE's vision of a petroleum free, emission free transportation system is a reality.

Fuel cells face a number of technical challenges including reducing the system's cost, size and weight while improving durability and performance characteristics. We also need to address manufacturing processes and materials issues. While substantial progress has been made on many of these fronts, more work needs to be done.

Cost is a major issue driven by volume as well as a number of technical factors. New technology, improved manufacturing processes, materials substitution and other strategies have been used to reduce fuel cell costs over the past two decades from $600,000 per kilowatt for the unique needs of the Space Shuttle orbiter application to $4,500 per kilowatt today for UTCFC's current PC25 stationary power plant with an annual volume of 50 units per year. We expect to be at $1,500-$2,000 per kilowatt by the end of 2003 with stationary volumes of 200 units per year, driving towards $50 per kilowatt for the automotive market when volume approaches one million units per year.

Continued investment in fuel cell core power plant technology is needed to reach these goals. We believe the government has a legitimate role to play in supporting high-risk fuel cell core technology R&D efforts on a cost-share basis with industry so the public at large can enjoy the efficiency, reliability and environmental benefits of fuel cell technology.

In addition to these technical challenges, the country also faces significant infrastructure hurdles such as hydrogen production, storage and distribution. The goal is to ensure the successful convergence of parallel efforts to meet fuel cell and hydrogen infrastructure performance goals. A fuel cell vehicle that meets all the performance targets will have very limited commercial viability without affordable and widespread access to hydrogen fueling capability, availability of service technicians to maintain the equipment and development and adoption of appropriate codes and standards to facilitate customer acceptance and use. All these issues need to be addressed simultaneously so there is no "long pole in the tent" holding back commercialization.

Practically speaking, this means hydrogen production, storage and distribution research and development efforts must be funded in tandem with research, development and demonstration efforts for the power plant.

This parallel R&D emphasis on core technology and infrastructure needs to embrace significant supplier involvement to maximize the opportunity for success. PNGV drew on expertise from 19 national labs and 400 organizations from 38 states. We urge that FreedomCAR continue this successful approach by incorporating and promoting significant involvement by the fuel cell power plant and supplier base, which we believe will accelerate the pace of technology deployment as well as generate innovative approaches.

It is essential that we harness the ingenuity, innovation and speed with which the supplier base brings technology to the market. For example, a FreedomCAR focus on fuel cell membrane suppliers will help bring down fuel cell system costs and based on a common stationary/transportation technology platform, these breakthroughs can be applied in the near term to buses, fleet vehicles and stationary applications.

BENCHMARKS FOR PROGRESS

Our nation's visionary goal to put a man on the moon first required launching primates into space. This was followed by manned orbits of progressively longer flights with more complex missions before the ultimate objective of the manned moon landing was accomplished. Similarly, our long-term objective of powering our economy with a renewable source of hydrogen is a revolutionary concept that will require an evolutionary approach.

UTCFC believes the sequence of this evolutionary process will include first the deployment of stationary power plants by the end of 2003 at a cost of $1,500-$2,000 per kilowatt that will start to be competitive in areas with high electricity costs such as California and New York. This will be followed by inner city bus demonstrations in the 2004-2005 timeframe and commercial availability in 2006. These milestones are on track and we believe will occur spurred by developments in California.

Transit buses are ideal candidates for the initial deployment of fuel cell vehicles. Hydrogen storage is not a problem because of space availability on the roof of buses. And hydrogen fueling stations and technician training can be made available given the relatively small number of inner city bus stations and service technicians.

Since the automotive application is the most demanding in terms of cost, weight, size, durability, ease of maintenance, start up time and other performance criteria, it is understandable that it will take longer for fuel cells to successfully compete in this market. But as we gain experience in deploying fuel cells for stationary, inner city buses and fleet applications, these successes can pave the way for zero emission personal vehicles and serve as benchmarks to measure progress towards the 2010 goals of the FreedomCAR initiative. It will be important to balance funding requirements so the fuel cell and hydrogen infrastructure R&D efforts as well as stationary and fleet vehicle demonstration programs receive appropriate levels of support.

ROLE IN ENERGY POLICY

The FreedomCAR initiative is a key element of a more comprehensive strategy to address heavy-duty vehicles as well as stationary power generation. This important effort will need to be coordinated with other key federal agencies such as the Departments of Transportation and Defense. It should also be integrated with strategies for these other fuel cell applications as indicated above. This will maximize the synergies that exist and leverage public and private investment.

SUMMARY

In summary, UTCFC believes DOE's FreedomCAR initiative is appropriately focused on hydrogen fuel cell powered vehicles as a key element of a comprehensive, long-term national strategy that will enhance energy security and deliver environmental benefits. Deployment of stationary fuel cells and inner city buses powered by fuel cells represent important milestones that will help us measure progress. R&D efforts should focus on fuel cell as well as hydrogen production, storage and distribution with the full involvement of the supplier community and national laboratories. Capturing and leveraging the synergies between the various fuel cell applications will maximize taxpayer benefit and accelerate the pace of deployment.

Thank you for the opportunity to testify. I would be happy to respond to any questions.

Mr. GREENWOOD. We thank you, Mr. Miller.

Dr. Paul?

TESTIMONY OF DONALD L. PAUL

Mr. PAUL. Chairman and members of the subcommittee. ChevronTexaco is pleased to have the opportunity to testify before the subcommittee on the FreedomCAR program and the future of advanced energy technologies. As ChevronTexaco's chief technology officer, I am involved in all facets of our company's energy technology, including fuel cell research and development, and can share our experiences about both key market incentives as well as the challenges to the development of new energy technology. Today, I will focus my testimony on our work in fuel cell technology applications, challenges to commercializing the technology, and public policy recommendations.

By way of background, ChevronTexaco is an integrated global energy company that produces oil, natural gas, transportation fuels, and other energy products. We operate in 180 countries, and employ more than 55,000 people worldwide. ChevronTexaco is the second largest U.S.-based energy company and fifth largest in the world. We consider ourselves to be an environmentally responsible company; and, in addition to supplying global energy, we are also involved in a whole host of advanced clean energy and fuel technologies.

We believe that fuel cell technology will continue to evolve. Stationary fuel cells to generate high-quality power are commercially available in selected operations today; however, we believe that mobile source fuel cells have a much longer timeframe for development given the complexities of the issues.

We continue to support development of fuel cell technology and the conversion of hydrocarbon fuels into hydrogen for use in fuel cells. We are actively working to develop safe methods for storing and delivering hydrogen in anticipation of future energy demands. To meet the numerous challenges involved with this new technology, we are involved in partnerships, participate in government and private workshops, and privately fund basic and applied research for hydrogen fuels and refueling stations.

An example of this type of activity is the California Fuel Cell Partnership, which was formed to explore pathways to commercialization of fuel cell vehicles, to demonstrate these vehicles in everyday driving conditions, and to demonstrate fueling options and other infrastructure needs. ChevronTexaco has been an active partner in the California Fuel Cell partnership since it was formed in 1999.

Challenges facing the development of the technology. First, the supply of hydrogen. Hydrogen is a fuel; it is not a natural resource; it must be manufactured from other sources. The two primary sources of hydrogen are water and hydrocarbons. For the past 50 years, we have been engaged in the conversion of hydrocarbons to hydrogen through refinery and gasification processes. We are leveraging our longstanding core competencies in fuels, catalysis, proprietary gasification, and process engineering technology to explore the development of a fuel processing business for hydrogen.

Reforming gasoline into hydrogen. An avenue that leverages the existing fuel infrastructure is to produce hydrogen onboard. We are collaborating to develop systems for the conversion of gasoline into hydrogen within a car. ChevronTexaco and General Motors are engaged in a multiyear research collaboration in support of General Motors' development of a gasoline-fed fuel cell for vehicles. One key component of this collaboration is the development of an economically producible gasoline that can be used in vehicles with fuel cells and conventional internal combustion engines. Providing consumers with this practical solution may help remove fuel availability as a near-term impediment to commercial fuel cell vehicle systems.

The delivery of hydrogen. One of the other challenges—one other challenge is how hydrogen would be distributed in a decentralized manner. We are trying to design a hydrogen refueling station that is economic and safe. Designing these stations requires incorporation of a range of new technologies, including hydrogen extraction, safe site storage technologies, stationary fuel cells to provide power at the site, and advanced hydrogen detection to control systems to make the station safe for consumer use.

Hydrogen storage. Distribution of fuels for commercial and consumer uses will require an infrastructure that must provide for hydrogen storage. We are currently engaged in the R&D and commercialization of a new hydrogen technology. Our focus is to produce safe, reliable products, using a common technology capable of meeting a wide range of applications, including small portable, automotive, and bulk storage applications.

Challenges to commercialization. We have operated in the refining and marketing business segment for over 100 years. The financial investment has been enormous. Integrated oil companies in the United States have generally been reducing their exposure to this business because of our inability to achieve a required return on capital. It is unlikely that U.S. refiners and marketers would create a substantial new infrastructure investment without believing they could obtain satisfactory economic returns. The interest—therefore, the introduction of fuel cell cars must be coordinated with the introduction of the infrastructure. Hydrogen must be available when and where it will be needed. We understand that customers must be confident that hydrogen will be available before they will buy cars powered by hydrogen.

It is likely that some of the first fleet refueling stations and even retail stations will make the hydrogen right at the station. We need codes and standards to be developed that will let us demonstrate this concept. They do not currently exist.

The challenge will be to build a network of large-scale industrial hydrogen generation facilities, pipelines, truck delivery systems, and smaller onsite generation facilities. The cost of hydrogen to consumers needs to be competitive in the marketplace with other energy fuels.

From our perspective it will take time to work through all of these challenges. Centralized fleets of fuel cell cars and buses are going to be important to get the infrastructure started and to prove the value and functionality of the fuel cell vehicle infrastructure. Specialty applications and niche markets that use much of the same technology but in different products are going to be important and will be signposts. We recommend the following:

One, consider the infrastructure as well as the technology. This should be a high priority in terms of DOE and other government R&D funds.

Two, manage public expectations to ensure that the public understands that this technology has a long time line.

Three, leverage private industry stakeholders. We believe that it will help make the technology commercial and also focus government priorities on areas where there is the most need.

Four, monitor market signals. Often we see that there are factors that change the need for particular technology, either increasing or decreasing its demand, and these factors need to be considered when it comes to looking at competing technologies as well.

Thank you for the opportunity to testify, and I will be happy to answer any questions.

[The prepared statement of Donald L. Paul follows:]

PREPARED STATEMENT OF DONALD L. PAUL, VICE-PRESIDENT AND CHIEF TECHNOLOGY OFFICER, CHEVRONTEXACO

Chairman Greenwood, Ranking Member Deutsch, and Members of the Subcommittee: ChevronTexaco is pleased to have the opportunity to testify before the Energy and Commerce Oversight and Investigations Subcommittee on DOE's FreedomCAR Program and the future of advanced energy technologies.

As ChevronTexaco's Chief Technology Officer, I am involved in all facets of our company's energy technology, including fuel-cell research and development, and can share our experiences about both key market incentives as well as challenges to the development of new energy technology.

Today I will focus my testimony on our work in fuel-cell technology applications, challenges to commercializing the technology and public policy recommendations.

By way of background, ChevronTexaco is an integrated, global energy company that produces oil, natural gas, transportation fuels and other energy products. We operate in 180 countries and employ more than 55,000 people worldwide. ChevronTexaco is the second-largest U.S.-based energy company and the fifth largest in the world, based on market capitalization. We consider ourselves to be an environmentally responsible company. In addition to supplying global energy, we are also involved in a whole host of advanced clean energy and fuel technologies.

We believe that fuel-cell technology will continue to evolve. Stationary fuel cells to generate high quality power are commercially available in selected operations today. ChevronTexaco is particularly optimistic about stationary fuel-cell applications and believes that mobile source fuel cells have a much longer time frame for development given the complexity of issues. For example, it was relatively easy for us to install Northern California's first commercial fuel-cell power plant, located at our office park in San Ramon, California. This fuel cell converts hydrogen from natural gas into electricity, clean water and usable heat, and provides secure digital-grade power to information technology systems. We undertook this project to gain experience with designing and installing stationary fuel-cell systems, and to help us translate this experience into other types of fuel cell projects. However, mobile source fuel-cell technology faces substantially more challenges.

CHEVRONTEXACO'S RESEARCH AND DEVELOPMENT INITIATIVES

We continue to support development of fuel-cell technology and the conversion of hydrocarbon fuels into hydrogen for use in fuel cells. We are actively working to develop safe methods for storing and delivering hydrogen in anticipation of future energy demands. To meet the numerous challenges involved with this new technology, we are involved in partnerships, participate in government and private workshops, and privately fund basic and applied research for hydrogen fuels and refueling stations. These efforts were under way prior to DOE's announcement regarding the FreedomCAR initiative; however, certainly this does provide an impetus for the private sector to focus its attention on the development of this technology. Unlike stationary fuel cells, this technology will require long-term development, especially with regard to fuel production and distribution infrastructure.

An example of the type of activity that we are involved in as a private/public partnership includes:

- *California Fuel Cell Partnership:* One of the most well-recognized initiatives is the California Fuel Cell Partnership, which was formed to explore pathways to commercialization of fuel-cell vehicles, to demonstrate these vehicles in everyday driving conditions, and to demonstrate fueling options and other infrastructure needs. ChevronTexaco has been an active participant in the California Fuel Cell Partnership since it was formed in 1999. This organization is a voluntary collaboration of 8 automakers, 4 energy companies, a number of State and Federal government agencies, and technology providers.

  Working with other energy partners, we are providing hydrogen to operate a project facility that safely delivers high-pressure hydrogen to demonstration vehicles. Today, the partnership is operating about a dozen fuel-cell vehicles at its West Sacramento facility.

Examples of our research and development activities, which reflect the many challenges facing the development of this technology, include:

- *Supply of Hydrogen:* Hydrogen is a fuel—not a natural resource. It must be manufactured from other sources, so how the supply system is developed is critical. The two primary sources of hydrogen are water and hydrocarbons. For the past 50 years, we have been engaged in the conversion of hydrocarbons to hydrogen through refinery and gasification processes. As you may be aware, oil refineries are the largest current producers and users of hydrogen. We are leveraging long-standing core competencies in fuels, catalysis, proprietary gasification and process engineering technology to explore the development of a fuel-processing business. The total environmental consequences of making hydrogen from any source need to be carefully evaluated. There needs to be a cost effective technology that enables fuel-cell systems to operate on readily available hydrocarbon fuels and to deliver hydrogen fuels at competitive costs. We have developed relationships with leading fuel-cell developers, utilities and suppliers in an effort to introduce competitive fuel-cell systems into the market. We have hydrogen fuel-processing systems under development that will convert a hydrocarbon feedstock, such as natural gas, into hydrogen.
- *Reforming Gasoline Into Hydrogen:* An avenue that leverages the existing fuel infrastructure is to produce the hydrogen on-board. We are collaborating to develop systems for the conversion of gasoline into hydrogen within a car. ChevronTexaco and General Motors are engaged in a multi-year research collaboration in support of General Motor's development of a gasoline-fed fuel cell for vehicles. GM is developing gasoline-fueled fuel cells as its interim strategy until a hydrogen infrastructure is established. This technology is largely based on fuel refining and related expertise, and is targeted to improve performance of converting gasoline-like fuels to hydrogen.

  Technology to convert gasoline to hydrogen in on-board processors has been demonstrated. However, to use a gasoline-like fuel to produce hydrogen, on-board a vehicle, it will be necessary to reduce sulfur to very low levels, below that of the cleanest fuels available today. Development of a method to reduce sulfur to very low levels is one of the main features of our research with General Motors. We also are investigating other modifications to gasoline that will be needed for use in fuel-cell systems.

  One key component of this collaboration is the development of an economically producible gasoline that can be used in vehicles with fuel cells *and* conventional internal combustion engines. As I will discuss in more detail later, the special infrastructure requirements, high costs and safety issues associated with hydrogen delivery are virtually prohibitive, at least in the near term. It is for this reason that we are working with GM to develop on-board fuel processors that will allow customers to use gasoline-like fuels that are familiar, the least expensive and use existing fueling infrastructure. Providing consumers with this practical solution may help remove fuel availability as a near-term impediment to commercial fuel-cell vehicle systems.
- *Delivery of Hydrogen:* One other challenge is how hydrogen would bedistributed in a decentralized manner. We are trying to design a hydrogen refueling station that is economic and safe. Designing these stations requires the incorporation of a range of new technologies including hydrogen extraction from natural gas, safe-site storage technologies, stationary fuel cells to provide power at the site, and advanced hydrogen detection and control systems to make the station safe

for consumer use. This is a daunting array of simultaneous technical challenges that we are excited to take on, but recognize that they will require involvement of many industry technology providers as well as public and government agencies to make them happen.

- *Hydrogen Storage:* Distribution of fuels for commercial and consumer uses will require an infrastructure that must provide for hydrogen storage. We are currently engaged in the R&D and commercialization of new hydrogen storage technology. Our focus is to produce safe, reliable products using a common technology capable of meeting a wide range of applications including small portable, automotive, and bulk storage applications. We are forming partnerships and associations with companies in various areas to coordinate our efforts.

CHALLENGES TO TECHNOLOGY COMMERCIALIZATION

We have operated in the refining and marketing business segment for over 100 years. The financial investment has been enormous. The current level of discretionary capital spending on the refining business segment by integrated oil companies has been close to zero. Integrated oil companies have generally been reducing their exposure to this business because of our inability to achieve a required return on capital. This has created an environment where refining assets have been sold for about 20% to 40% of replacement cost. It is estimated that six to nine refineries may be up for sale in the U.S. within the next 12 months either because of weak business conditions or Federal Trade Commission mandates. It is unlikely that U.S. refiners and marketers would create a substantial new infrastructure investment without believing that they could obtain a satisfactory economic return to compensate for this risk.

The introduction of fuel-cell cars must be coordinated with the introduction of the infrastructure. We know that the infrastructure must be in place before customers buy these cars. We also know that this will require significant investment with a minimal return initially until widespread adoption occurs.

In addition to the financial risks outlined above, we see the following additional challenges to the commercialization of this new technology and infrastructure:

Hydrogen must be available when and where it will be needed. We understand that customers must be confident that hydrogen will be available before they will buy cars powered by hydrogen. It is a significant task to develop technology to:

1. produce the hydrogen at a reasonable cost;
2. deliver it over a broad geographic area;
3. store it at the sales point;
4. fuel the cars; and
5. in addition, the technology must be employed in a safe manner to achieve total consumer confidence.

There are 9 million tons per year of hydrogen produced and used in the United States. Worldwide production is 40 million tons per year. Most of this hydrogen is used in refineries, chemical plants, metals processing and the electronics industry. Hydrogen right now is a specialty chemical, and it must be transformed into a broader energy fuel as it begins to be used for transportation.

Storing hydrogen in the car, at the refueling station and throughout the delivery infrastructure is a sizable, unfulfilled challenge. The problems are different at each location, and they each deserve the attention of industry, national labs and the DOE. Much attention is given to storing hydrogen on board the car, and rightly so, but similar attention is needed in the other places that hydrogen needs to be stored. This technology still needs to be developed, tested and embraced.

It is likely that some of the first fleet refilling stations and even retail stations will make the hydrogen right at the station from reforming natural gas. We need codes and standards to be developed that will let us demonstrate this concept; they do not currently exist.

Eventually the hydrogen market may be big enough that we can make hydrogen in large centralized plants, similar to refineries today. But this still needs to be distributed across the country. The challenge will be to build a network of large-scale industrial hydrogen generation facilities, pipelines, truck delivery systems and smaller on-site generation facilities—all expanding as an economic market develops due to increasing consumer acceptance of fuel-cell vehicles.

Once large centralized plants are built, it will be possible to capture a significant portion of the carbon dioxide made as a by product. Capturing, inertly storing or sequestering large volumes of CO_2 are two distinct challenges yet to be solved.

New codes and standards need to be developed that permit the development of the infrastructure. Existing building codes and hydrogen system design standards were not developed with consumer applications in mind. Today's codes provide large distance "setbacks" from other facilities that limit the locations where hydrogen can be manufactured, stored and dispensed. This was appropriate for the technology and hydrogen applications of the 20th century, but they make retrofits of existing sites with limited area for expansion impractical for future hydrogen facilities. Codes and standards will need to be updated to reflect the developments in safer hydrogen technologies arising from the new storage and control system technologies. In some cases, building codes will need to strengthened to ensure safe maintenance facilities. In all cases, revisions of the codes will need to occur simultaneously with developing hydrogen technologies.

The cost of hydrogen to consumers needs to be competitive in the market with other energy fuels. We need to be convinced that hydrogen can compete with other fuels in the market. This looks achievable once the demand for hydrogen is substantial, but as of yet this has not been demonstrated. The ability to supply hydrogen to the market while the demand is very low is difficult.

From our perspective, it will take time to work through all these challenges. Centralized fleets of fuel-cell cars and buses are going to be important to get the infrastructure started and to prove the value and functionality of the fuel-cell vehicle and infrastructure. Specialty applications and niche markets that use much of the same technology but in different products are going to be important and will be a signpost along the path. One opportunity in this area would be for use of the technology by the military. In addition, applications, such as airport ground equipment vehicles and fleets of industrial vehicles with centralized and stationary refueling, need to be successful before consumers become a significant user of this technology.

PUBLIC POLICY RECOMMENDATIONS

We believe that there are several areas that are critical to the development of the technology and the need for a public-private partnership. We recommend the following:

1. *Consider the Infrastructure As Well As The Technology:* It is absolutely critical that DOE work on the infrastructure issues simultaneously. Although technology can be developed, it will not be implemented until there is an infrastructure to support it. Energy companies have a large role to play in the development. This should be a high priority in terms of DOE and other government R&D funds.
2. *Manage Public Expectations:* When new technologies are on the horizon, there is a lot of fanfare and media attention surrounding the development of the technology. Unfortunately, this leads to unrealistic public expectations that such technology will be readily available within a short time frame. We believe that it is critical and responsible to ensure that the public understands that this technology has a long timeline, and not create unrealistic or false expectations.
3. *Leverage Private Industry Stakeholders:* DOE has held a number of meetings bringing together public and private industry stakeholders. We believe that this will help make the technology commercial, and also focus government priorities on areas where there is the most need.
4. *Monitor Market Signals:* Often we see that factors can change the need for a particular technology—either increasing or decreasing demand. Some of these factors may include competing technologies, availability of resources, public opinion, etc. For example, we expect that hybrid cars are going to increase the fuel economy of future cars and impact the market. To embark on a long-term major government initiative without doing mid-course reviews would be a mistake. By doing periodic full reviews, there would be an opportunity to steer or change policy as needed and implement appropriate mid-course corrections.

I should note that pending energy legislation, now in a House-Senate conference, does include several provisions to address issues related to this technology as well as other advanced energy technologies.

Thank you for the opportunity to testify and I would be happy to answer any questions.

Mr. GREENWOOD. Thank you, Dr. Paul.

Let me start with you, Dr. Roan, and your comparison of the various vehicles and their efficiencies and the amount of fuel used, and particularly the amount of CO_2 emitted. My recollection—I don't know if we can get those slides back up, but my recollection was that it was a hybrid that took the blue ribbon; is that correct?

Mr. ROAN. In terms of using petroleum fuel today, that's correct. Now, that's the diesel or compression ignition hybrid. And that's why I personally believe that continuing the research—the government-sponsored or supported research on the exhaust emissions, both at the source, meaning combustion process and cleanup, is important.

Mr. GREENWOOD. What are the challenges in getting that diesel, that diesel engine, widely used in the marketplace?

Mr. ROAN. Well, I probably am not the best one to ask, someone from the industry would be better, but I can give you my opinion. I think that there really are two.

No. 1 is, of course, the problem in meeting the EPA and the California emission requirements. That's extremely difficult for diesels. No. 2, of course, is the image.

Mr. GREENWOOD. I think you were present when Mr. Dingell was making inquiries about the sulfur content of fuel. Is it your understanding that if we were to succeed in getting close to zero sulfur content, that, in fact, that would eliminate that concern, and, in fact, move us very quickly toward very significant fuel efficiency?

Mr. ROAN. I don't believe that that eliminates the concern, but I do believe that it's a great big help. I think that it helps considerably, and especially in terms of the alternatives for emission treatment. There still is the issue of particulates to deal with and the— it's very difficult for the diesel engine to meet it; however, I do think it's possible, especially with very low sulfur fuel.

Mr. GREENWOOD. What about—what's the most positive thing we can say about the amount of CO_2 that we will be putting into the atmosphere in the best of all scenarios? That's the question I would pose to any of you.

Mr. ROAN. Right now we would be minimizing the amount of CO_2 that we put in the atmosphere either with this compression ignition hybrid vehicle, or with the hydrocarbon fuel cell hybrid vehicle. I believe that, ultimately, there would not be much difference in terms of the fuel efficiency, and the fuel cell would have an advantage with respect to emissions. The fuel cell would not have the difficulty in meeting the emission requirements that the diesel does.

So, those two, I think, are our best bet using petroleum.

Mr. GREENWOOD. Mr. Miller?

Mr. MILLER. Well, I would just say you could eliminate CO_2 entirely if we get to the point where we can produce electricity through a renewable means, either through wind or solar or through nuclear. And then you electrolyze water to produce hydrogen, and then you use the hydrogen in cars to transport people, you would literally have no CO_2 emissions in that type, if we get to that point of where we get power from—if we can find power from renewable means.

Mr. GREENWOOD. Dr. Paul.

Mr. PAUL. Yes, Mr. Chairman. One way, probably a third option—all of those, I think, are options. A third option is if you were able to have an infrastructure that allowed for a large central production of hydrogen where you could capture and sequester the CO_2, you would have effectively the same situation.

Mr. GREENWOOD. And how would you do that?

Mr. PAUL. How would you capture it?

Mr. GREENWOOD. How do you sequester the CO_2?

Mr. PAUL. Well, there are challenges there, as you are probably aware, but there is a considerable amount of research effort going on in the industry as well as in the DOE around finding geologic formations where one could inject and sequester CO_2, for example, in the subsurface. And there are, in fact, a number of projects looking specifically at the options for capture and sequestration of CO_2.

Mr. GREENWOOD. A question for each of you gentlemen. We saw—in the previous panel we saw the graph of petroleum utilization by this country. It's heading upward. What is a realistic scenario based on the technology, the research that we are doing on all of this automotive technology? What is a realistic scenario in which we see—is there a realistic scenario in which we see that trend line take a negative direction?

Mr. ROAN. Well, I will give you comments on some of the things that were discussed along that line. First of all, nothing is probably going to cause it to decrease for the immediate future, because the mechanism is already in place for a continuation of the increase. The thing that's going to cause it to decrease, of course, is if we consume less petroleum, and this means that either the consumers are restricted in the amount of petroleum that they can use, or the vehicles are restricted in the amount of fuel that they can consume; or, that there is some kind of a strong incentive for the consumer to want to use the higher-mileage, lower petroleum-consuming vehicles.

Mr. MILLER. I would say for the next 10 years, the trend line is going to be difficult to change, but if we do get fuel cell cars on the road in the next decade, they would be powered by hydrogen, probably coming from natural gas; and, instead of importing oil, we have a lot of more resources in terms of natural gases in North America than—and that could change the trend line from importing petroleum.

Mr. GREENWOOD. Dr. Paul.

Mr. PAUL. I would agree with both gentlemen here. Basically the issue to drive down petroleum use is the fundamental energy demand in the system, the efficiency of the system. Looking at a broad array of technologies that introduce and improve energy efficiency, this is certainly one of the programs and one of the big sources of the use of energy. But I think it's a broad-based issue of improving energy efficiency and use in the U.S. to track down overall petroleum and natural gas.

Mr. GREENWOOD. Looking specifically at the FreedomCAR program, are there—given the challenges, the visions that you have outlined in your testimony and in your response to the questions, do you believe that the existing program as it is functioning now is on the right track? Do you think or would you recommend the Congress make significant changes, or even minor changes in the program to get us where we want to go sooner?

Mr. ROAN. My personal opinion is that I do believe it's on the right track; however, as you can see from some of the things I've said, I see enormous pitfalls in getting to the capability to produce hydrogen and also the infrastructure. And so I think that it has to be reviewed often and carefully to see about the progress being made, and to make sure it is going in the right direction.

Mr. GREENWOOD. Mr. Miller.

Mr. MILLER. In general, we support the FreedomCAR program. I would say—I would like to add one thing and emphasize one thing, which is we believe in this evolutionary model. It's like in the computer industry. If, before computers were invented, we tried to invent the PC, it never would have happened. You had mainframes, and then you went to the first PCs, and now we are today where everyone can afford them.

I think the same thing is going to happen in the fuel cell industry. That's why we think it's important for the Federal Government and DOE to support the introduction of stationary fuel cells, which can afford to pay the most for fuel cell technology, then buses, and then cars. And we think it will be that evolution over the next 10 years which gets us—and it will also keep businesses and suppliers interested, because they will be getting revenue serving as suppliers to the fuel cell industry over that period of time as opposed to continuing to try and fund research in the hopes that 10 or 12 years from now there will be a payoff.

So we think it will be an evolutionary process, and we think it's important for the government to focus on the interim steps as well.

Mr. GREENWOOD. Mr. Paul?

Mr. PAUL. Yes. I would say, in general, we do support the program. As I discussed in my remarks, it is important to ensure that the program includes these infrastructure elements. I would also say that it's important that some of the basic research that sits underneath the technology development continue. Research in areas like surface chemistry, material science, memory and technology, and things like that are extremely important because they support the broad platform around fuel cell technologies that will have a broad array of applications in addition to perhaps the central feature of transportation.

Mr. GREENWOOD. How do—what are your views on Congress increasing the CAFE standards? I think it was Dr. Roan who said that, in the absence of essentially government efforts or impositions on fuel utilization, that we were going to continue an upward trend for the foreseeable future. What do each of you think about Congress increasing the average fleet efficiency?

Mr. ROAN. I—there are so many issues involved there that I hesitate——

Mr. GREENWOOD. I don't have anybody here to take the microphone, so it's okay.

Mr. ROAN. I think that it is going to work better if there is an incentive for the industry to make more fuel-efficient vehicles, such as hybrids, which they seem to be intending to do, and for the consumers to buy them. The CAFE standards have probably served a good purpose, and it's certainly conceivable to me that it could do the same thing again, that it could bring fuel consumption down. It seems to be kind of a hard way to do it—a tough way to do it, I should say, but I think it could work.

Mr. GREENWOOD. Mr. Miller, do you have views on that subject?

Mr. MILLER. Well, let me answer it may be in a little roundabout way. I would just note that the State of California has put in very strict guidelines for emissions of a certain percentage of each manufacturer's fleets for cars in the 2007/2008 timeframe. I believe that's been instrumental in getting most of the major auto manufacturers to spend in excess of $100 million each annually to go pursue fuel cell vehicles.

California also has legislative requirements on buses for transit agencies, and the result of that is that many of the bus transit agencies are starting to purchase small fleets of fuel cell buses. And so the State of California is taking a leading role, and consequently industry is responding because of how large that market is.

Mr. GREENWOOD. Dr. Paul.

Mr. PAUL. Chairman, Texaco has not taken a position on CAFE standards. We just feel that's not our business.

Mr. GREENWOOD. Okay.

The Chair recognizes the gentleman from Kentucky for 5 minutes for questioning.

Mr. FLETCHER. Thank you, Mr. Chairman.

I had just a brief chance to look over your testimony. Forgive me for being a bit late and having to run to vote. But, Mr. Miller, you mentioned in the testimony that, practically speaking, how does—your production and storage distribution R&D must be funded in tandem with R&D in efforts for a power plant. Do you believe that the FreedomCAR sufficiently pursues this course now? And what are your thoughts on that?

Mr. MILLER. I think the FreedomCAR program, DOE is absolutely focused and is funding research efforts in both hydrogen storage and hydrogen production. And so, you know, I don't have any substantial disagreement with the program as it stands now.

Mr. FLETCHER. Let me ask you a question in general. And I know this is all fairly new to me, other than we used to talk about these things years ago when I was in engineering, but what would you say, before you start looking at these things being marketable, if we strictly did it on a market basis. What would the price of gasoline have to get at the pumps before you would think that this would be competitive and that, from a consumer standpoint, it would be something they choose based on that, without government being much more involved?

Mr. GREENWOOD. Mr. Miller?

Mr. MILLER. Yes.

Mr. GREENWOOD. And I will be glad to hear from the others, too, committee members as well.

Mr. MILLER. That's a good question. I don't have—I might go back to our people and ask them that question. I don't have a specific dollar number for the price of gasoline where it would really encourage—it would really depend on the cost of hydrogen production.

Mr. PAUL. Yes. We—this is a—the price that one could model in a scenario of the future is a very complex issue, involves the cost of the infrastructure and the distribution system, the state of—the number of cars and a lot of other things. I don't think there has been a—there is a number that one could put forward at this time. But I will say that a lot of people are looking at this as a strategic issue, but I couldn't give you a good number at this point.

Mr. GREENWOOD. Okay. Let me go back, I guess.

Mr. FLETCHER. You mention in your testimony—and this may have been asked since I was not here all the time, Mr. Chairman—

but in any case, other interim strategies for using fuels such as natural gas to achieve fuel efficiency gains, has this been given sufficient consideration or does it conflict with the goals outlined in FreedomCAR and the hydrogen vision?

Mr. ROAN. The issue of natural gas, I don't believe, is treated specifically in the FreedomCAR program. The issue of hydrogen production is. I mentioned the natural gas because I have felt for a long time that we could have a major problem there. If we provide hydrogen through the conversion of natural gas and steam, which is what we're doing now, and if we use additional natural gas to produce the additional electricity that we would need to produce hydrogen, then I believe we would be simply importing natural gas, liquefied natural gas, in much, much larger quantities than we could get it. And we would with petroleum. So I see the efficient use of natural gas as a very important part of our energy strategy personally.

Mr. FLETCHER. Well, in addition, do you think the FreedomCAR program, at least as it's currently outlined, do you believe it's sufficient to really address the various challenges that your testimony pointed to?

Mr. ROAN. I do because of the fact that they included in the FreedomCAR programs continued research on the exhaust treatment for the diesel engine, and I think that the diesel hybrid may prove to be one of our most efficient transportation systems. They also include additional research, insofar as hydrogen carbon-fueled fuel cell vehicles is concerned, and I think that that's a very clean alternative and a very fuel-efficient alternative to transportation. Both of those would give us a big increase over the conventional vehicle. So—and DOE is proposing to do this in addition to the hydrogen fuel cell and the storage and the production and infrastructure issues.

So I think, yes, I do agree that they are on the right track.

Mr. FLETCHER. Let me ask just—and it'll be a final question, a kind of follow-up. If you could look in a crystal ball, and I know that is difficult to do, but if you're looking at hydrogen and some of the other alternative fuel systems, transportation systems, where do you see down the road that these are going to really become significant? I know we have some, certainly hybrid cars now, but when you're looking at hydrogen, when do you see, if you looked into a crystal ball, that that may be something that we grow accustomed to on a daily basis?

Mr. ROAN. That is pure speculation. I mean, it's really very hard to tell, but I would see at least two decades, maybe three decades, before we would have much hope of getting to that point.

Mr. MILLER. I would answer it just by once again focusing on this issue of an evolutionary change in the industry. I believe you're going to see many, many fuel cell buses in the second half of this decade, and it could be that by 2010 almost all—most buses are fuel cell buses, because fuel cells are extremely efficient, and they're extremely efficient at low power or at part power, which is what inner-city driving cycles are all about.

Cars, it's certainly going to be substantially beyond that, sometime in the following decade.

Mr. PAUL. That is very consistent with our perspective. I would like to reiterate the support for the evolutionary view with fuel cell technology extending across stationary power, fleets, special purpose applications, building that out extensively over the next decade, and—but I think for a large distribution of fuel cell vehicles as consumer items, I think you have to think multidecade timeframes.

Mr. GREENWOOD. The gentleman has no—Mr. Miller, did you want to comment?

Mr. MILLER. No, that's fine.

Mr. GREENWOOD. The time of the gentleman from Kentucky has expired. The Chair recognizes the ranking member, Mr. Deutsch.

Mr. DEUTSCH. Thank you. Dr. Paul, the EPA has informed us that it's feasible to reduce sulfur content of diesel fuel to less than 15 parts per million with existing technology. Given what we know now about the benefits of low-sulfur diesel fuel, why is it the petroleum industry in the United States has not yet reduced the sulfur content in diesel?

Mr. PAUL. Well, I would like to say with respect to—respectfully, with respect to our activities, we're actually converting our major refinery in Pascagoula, Mississippi to produce a low-sulfur diesel actually well ahead of the date. So I think that there are members of the industry that are beginning to make these changes. So my response would be that we're making the changes. I believe other members of the industry are doing so as well.

Mr. DEUTSCH. You're only converting one refinery. Is that it?

Mr. PAUL. We're converting the Mississippi refinery at this point in time. We already make clean air gasoline in California.

Mr. DEUTSCH. Uh-huh. All right. Dr. Paul, you testified that U.S. refiners and marketers would not be willing to make a substantial infrastructure investment without a satisfactory economic return. If the U.S. auto makers are willing to widely produce vehicles powered by low-sulfur diesel, would you be willing to make the fuels to support the significant investment?

Mr. PAUL. We will always make fuels that meet the market, but when—at the same time, one has to decide on capital that it takes to build the infrastructure to meet the market. So those two things I believe go in concert. But we will always strive to deliver fuels that customers demand in the market.

But the infrastructure issues with fuel production and distribution and sales are very challenging, and historically have not delivered in satisfactory terms.

Mr. DEUTSCH. Interacting with the auto makers, I mean, the auto makers build the infrastructure, again this chicken-and-egg-type thing. At what point do you start building the infrastructure?

Mr. PAUL. For new fuels?

Mr. DEUTSCH. Correct.

Mr. PAUL. We of course change fuels—make adjustments to refineries to meet environmental requirements, as I mentioned before with the low-sulfur diesel, and as we have for many years in clean air gasoline in California. We make infrastructure investments when we believe that the timing of the investments and the emergence of the markets will support such investments.

Mr. DEUTSCH. I want to go back to a question I asked the panel, and some of you have touched on it, but just to give a time horizon. If each of you can respond, how long will it take to develop a fuel-cell-powered vehicle for mass production in the United States? Dr. Roan.

Mr. ROAN. The big issue in developing the vehicle is the cost, as already was pointed out by Mr. Garman. The progress has been extremely encouraging. In about a 10-year period, we've had about a factor of 10 decrease in the predicted price, as well as the size. I think that the progress is going to continue. I think that the industry is going to be continuing, as well as the work done in the national labs and supported by the government.

We have quite a ways to go. So I think that probably before we're looking at mass-produced vehicles that would be competitively priced so that people would actually buy them, probably 10 years.

Mr. DEUTSCH. Mr. Miller.

Mr. MILLER. 2010. I think there are auto manufacturers today with plans. Whether they eventuate or not is another thing, but they have plans, 2010.

Mr. DEUTSCH. Dr. Paul.

Mr. PAUL. Yes, I would agree.

Mr. DEUTSCH. 2010?

Mr. PAUL. Yeah.

Mr. DEUTSCH. Whoever feels comfortable answering this. But wouldn't widespread use of hydrogen-powered vehicles almost double the demand for electricity in the United States?

Mr. ROAN. I'm sorry. I didn't hear the last——

Mr. DEUTSCH. Would the widespread use of hydrogen-powered vehicles double the demand for electricity in the United States?

Mr. ROAN. Not right now, because——

Mr. DEUTSCH. But if it were to occur.

Mr. ROAN. If we're using renewable energy source—or using electricity, electrolysis of water to produce the hydrogen to convert our personal vehicle fleet would roughly double the amount of electricity we're using for our residential applications right now.

Mr. DEUTSCH. Do either one of you want to respond? Is that the conventional wisdom in terms of the industry at this point?

Mr. MILLER. I would say I think there's a debate as to whether you'll produce hydrogen through electrolysis or through reformation of a hydrocarbon, and if it happens through the reformation of a hydrocarbon, in other words, breaking those hydrogen and carbon bonds, then you wouldn't increase electricity at all, I don't think.

Mr. DEUTSCH. Then you're still using the same original basis, then, in terms of—you know, where you're going to—all right. Thank you.

Mr. GREENWOOD. The Chair thanks the gentleman and recognizes the gentleman, Mr. Stearns, for 5 minutes for inquiry.

Mr. STEARNS. Thank you, Chairman. Again, I welcome Dr. Roan from the University of Florida. Dr. Roan, I at my home where I am here in Virginia, I heat the apartment with gas, and down in Florida I use gas to heat my home. And when you transition to this FreedomCAR and the use of hydrogen, don't you—won't we use a lot of gas in this country to do that?

Mr. ROAN. Yes, sir. If we continue making hydrogen the way we do now, which is primarily through the steam reformation of natural gas, we would dramatically increase the amount of natural gas that we would use if we are talking about large numbers of vehicles and the supporting amount of fuel to power those vehicles. It would be a great deal of gas.

Mr. STEARNS. I think what I'm trying to get at, are we actually going to exhaust in doing—in doing this, that we might exhaust our domestic supply of natural gas, because a lot of homes, particularly in the Northeast, are using gas. So this goes back to what I tried to touch on earlier with Mr. Garman, and also Mr. Wells when I asked him relative to the use of petroleum products, to get the hydrogen developed, the production of hydrogen, we're going to use a lot of petroleum. So my question to you is, would you say that we're going to actually exhaust or perhaps—because we don't have the same kind of gas supply, and we're using more and more gas. So is it possible we're going to exhaust our gas supply in-country to do this?

Mr. ROAN. I don't consider myself an expert in that area, but based on the numbers I have seen, I believe we put in something like 22,000 new gas wells last year and roughly broke even, and that we're projecting that our imported liquefied natural gas is going to increase, and that is even without using natural gas to make large quantities of hydrogen. So I would have to say that, again, based on what I've read, the reports and so forth, it seems to me as though we could get into a very serious problem with the availability of natural gas.

Mr. STEARNS. I'm surprised Mr. Garman didn't sort of agree with what I told him about petroleum. I didn't ask about gas.

The idea of the new exploration and production in this country of gas is not going very well, is it? I mean, are there incentives in place that—when we talk about ANWR for gasoline products—but there doesn't seem to be the new exploration, new production of gas. So we have a problem if we continue this FreedomCAR as a long-term, long-range objective, and at the same time we don't seem to have the incentives to get more gas production.

Mr. ROAN. Right now gas is still quite cheap even compared to petroleum. As I remember, the number is on the order of about $4 per million Btu for natural gas as opposed to about 6 for petroleum. And I think, if that's what you were asking, I don't think there's a strong incentive there in terms of——

Mr. STEARNS. Let me ask Dr. Paul or Mr. Miller what your feeling is about the thrust of my——

Mr. PAUL. I guess in my remarks, the supply of hydrogen is the issue and——

Mr. STEARNS. What did you just say?

Mr. PAUL. The supply of hydrogen, how you make the hydrogen, and certainly today reforming natural gas is the most common way in which to make hydrogen for commercial use in either fuel cells or for industrial processes. One of our major research efforts, and I believe anyone that is involved in the hydrogen supply business, is how to reform other things in which there may be much—may be much more plentiful.

One that Dr. Garman mentioned that we've been actively involved in the technology—in fact, we have over 100 plant licenses around the world—is to basically gasify coal refinery bottoms, residuals, very low—in effect low-grade carbons, out of which you do in fact produce hydrogen as part of the stream. So it is possible to make a broader array of sources through technology, turn them into hydrogen; rather than right now the most attractive one, which is to reform gas.

Mr. STEARNS. So, Dr. Paul, you would say we would not be in danger of exhausting our supplies of natural gas?

Mr. PAUL. I think that the conversion of natural gas to hydrogen is one of the many demands for natural gas but, you know, burning it in power plants for electricity is certainly a much, much larger market.

Mr. STEARNS. So yes and no. Do you agree with Dr. Roan that we would possibly exhaust our natural gas supplies at the present rate we're going if we had to develop the hydrogen production?

Mr. PAUL. In terms of would our use of natural gas—U.S. supplies, of course——

Mr. STEARNS. Yes.

Mr. PAUL. [continuing] as opposed to the global supply of natural gas——

Mr. STEARNS. We would become more dependent on somebody else?

Mr. PAUL. Would this demand rise? My guess is that gas demand will rise.

Mr. STEARNS. Okay. And, Mr. Miller, do you——

Mr. MILLER. I'm not an expert in that area.

Mr. STEARNS. Dr. Roan, the last question is do you believe the National Research Council can continue to play a role in reviewing and advising on the progress of this research? As I understand from staff, these folks, the National Research Council, are not quite involved. And I guess the question is, should they continue to play a role; and, perhaps, why aren't they playing a bigger role?

Mr. ROAN. To my knowledge, they are not involved right now, and my speculation would be that it's too early to even—to set up the mechanism to do this. But in terms of the first question, I believe that this involvement played a very positive role in the PNGV program. I think it was extremely helpful. And I think that the same thing would be true, insofar as the FreedomCAR program is concerned. I do think that the National Research Council could play a very important, positive role there.

Mr. STEARNS. Thank you, Mr. Chairman.

Mr. GREENWOOD. Thank you, Mr. Stearns. The Chair thanks our witnesses for your testimony this afternoon. You are excused, and this hearing is adjourned.

[Whereupon, at 12 noon, the subcommittee was adjourned.]

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RESEARCH AND DEVELOPMENT

Lessons Learned from Previous Research Could Benefit FreedomCAR Initiative

Statement of Jim Wells, Director
Natural Resources and the Environment

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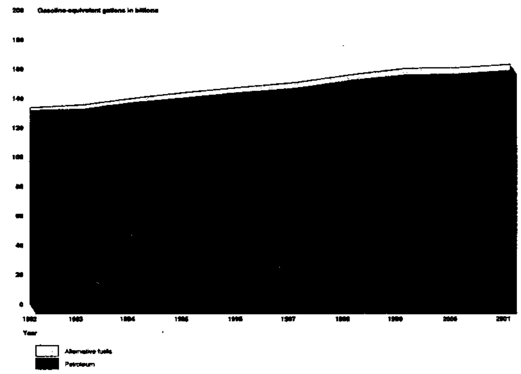
Mr. Chairman and Members of the Subcommittee

We are pleased to be here to discuss our previous work on federal research and development (R&D) initiatives that provide some useful insight as Congress considers the FreedomCAR initiative.[1] As you know, one of the major challenges facing the nation is to reduce the consumption of petroleum in the transportation sector. Transportation represented about two-thirds of total U.S. petroleum consumption and roughly one-quarter of total national energy consumption. Furthermore, the United States consumes about 45 percent of the gasoline consumed in the world. The nation's continued reliance on petroleum makes the sector highly vulnerable to the uncertainties of the world oil market and greatly increases the difficulty of achieving clean air objectives.

Over the past 25 years, the federal government has spent billions of dollars attempting to reduce the consumption of petroleum in the transportation sector. Throughout the period, we have tried a variety of means, such as tax incentives, mandates to use vehicles that run on alternative fuels, and laws designed to enhance fuel efficiency. More recently, the federal government conducted a $1.2 billion partnership between industry and government, the Partnership for a New Generation of Vehicle (PNGV), which focused on developing a highly fuel-efficient car. Clearly, some of these efforts, along with industry advances, have made many vehicles more fuel-efficient and less polluting than vehicles were a generation ago. However, any gains in fuel efficiency have been outpaced by increases in the total miles driven and the growing popularity of less fuel-efficient sport utility vehicles and light trucks. As a result, as shown in figure 1, the total amount of petroleum our vehicles consume continues to rise.

[1] See Related GAO Products.

Figure 1: Trends in Motor Vehicle Consumption of Petroleum and Alternative Fuels, 1992 through 2001



Note 1: Alternative fuels include ethanol and MTBE used as oxygenates in gasoline.

Note 2: Year 2002 data are forecasts.

Source: Energy Information Administration.

Further, about 97 percent of the total motor vehicle fuel consumption comes from petroleum. This is because consumers have not widely embraced vehicles that run on alternative fuels, such as natural gas, ethanol, or liquidified petroleum gas. As we have reported, these vehicles are often more expensive than traditional vehicles, few refueling stations are available, and the price of gasoline is lower today in real terms than the 30-cents-per-gallon gasoline sold in 1960.[2]

[2] U.S. General Accounting Office, GAO/RCED-00-59, *Energy Policy Act of 1992: Limited Progress in Acquiring Alternative Fuel Vehicles and Reaching Fuel Goals* (Washington, D.C.: Feb. 11, 2000).

In this context, the Administration has proposed a new initiative, known as FreedomCAR. Although the initiative is still in its early stages, it appears to be focused on developing hydrogen fuel cells that will provide the technology necessary to create cars and trucks that are free from petroleum and have no polluting emissions—without sacrificing safety or convenience. FreedomCAR will operate as a cooperative research effort between the Department of Energy and the automakers General Motors, Daimler-Chrysler, and the Ford Motor Company. The department has requested $150 million for FreedomCAR in fiscal year 2003 and will require additional funding for the initiative over the next 10 to 15 years.

As Congress considers the FreedomCAR initiative or any comparable federally sponsored research program, we would like to suggest four themes for congressional oversight, based on the lessons learned from 20 years of our work on R&D in many areas. Specifically, as you oversee the initiative, you may want to make sure that it

1. performs research that private industry would not do on its own,
2. specifies a clear and measurable goal,
3. devises a strategy to directly address that goal, and
4. considers whether consumers will buy the products resulting from the R&D.

While these lessons seem like common sense, let me elaborate a bit on each, using examples from previous GAO work to show how each is crucial to an R&D project's success.

Perform Research That Private Industry Would Not Do on Its Own

To ensure federal funds are being spent wisely, it is important to ask, "Would the private sector do the research without government funding?" Federal R&D programs have not always considered whether the federal funding is merely displacing private research rather than spawning new work. For example, when we spoke a few years ago to participants in the Department of Commerce's Advanced Technology Program (ATP), about 40 percent of program participants told us they would have performed the research done as part of the program even without federal funding.[3] Before

[3] U.S. General Accounting Office, GAO/RCED-96-47, *Measuring Performance: The Advanced Technology Program and Private-Sector Funding* (Washington, D.C.: Jan 11, 1996).

funding particular ATP projects, the Department of Commerce now considers whether industry would perform the R&D even without federal funding.

Specify a Clear, Measurable Goal

To be effective, any R&D program must be directed towards a clear goal and be reassessed periodically to see if the goal is still worth pursuing. For example, we noted that SEMATECH, the federal and industry consortium formed in 1987, succeeded in part because it clearly articulated both a goal—improve the competitiveness of U.S. manufacturing in semiconductors—and a method to achieve this goal—by building a state-of-the-art semiconductor using only equipment built in the United States.[4] In contrast, in 2000, we said a significant problem with the Department of Energy's performance plans for its "Science and Technology" business line was that the department did not clearly articulate its goals.[5] For example, the department sought as a goal to "pursue technology research partnerships with industry, academia, and other government agencies" without stating why it wanted to do so or how the goal helped to achieve the department's overall missions. We also reported that, although the PNGV began with a clear goal of developing a highly fuel efficient family sedan, the partnership did not later reassess the goal as consumer tastes shifted away from family sedans and towards light trucks and sport utility vehicles.[6]

Devise a Strategy That Directly Addresses the Goal

Although it may sound surprising, government-sponsored R&D programs have sometimes articulated a goal but then devised a strategy that did not directly address the goal. For example, in 2000, we noted that the Department of Energy sought to achieve one of its performance goals, "diversify the international supply of oil and gas," in part by continuing "leadership in international energy initiatives"—a strategy that seems

[4] U.S. General Accounting Office, GAO/RCED-92-223BR, *Federal Research: SEMATECH's Technological Progress and Proposed R&D Program* (Washington, D.C.: Jul. 16, 1992).

[5] U.S. General Accounting Office, GAO/RCED-00-268R, *Government Performance and Results Act: Information on Science Issues in the Department of Energy's Accountability Report for Fiscal Year 1999 and Performance Plans for Fiscal Years 2000 and 2001* (Washington, D.C.: Aug. 25, 2000).

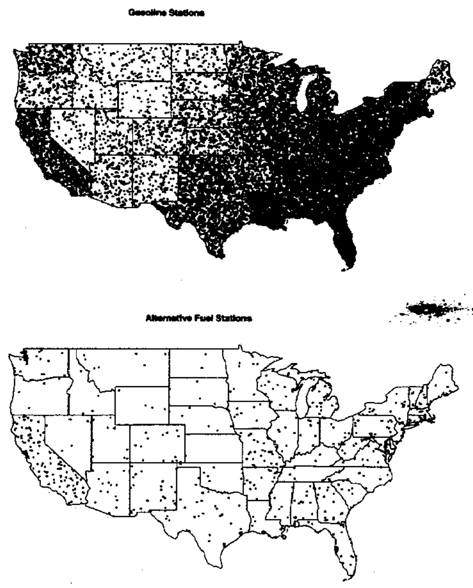
[6] U.S. General Accounting Office, GAO/RCED-00-81, *Cooperative Research: Results of U.S.-Industry Partnership to Develop a New Generation of Vehicles* (Washington, D.C.: Mar. 30, 2000).

somewhat vague and only tangentially related to the goal.[7] Similarly, the Energy Policy Act of 1992 established goals that alternative fuels replace at least 10 percent of petroleum fuels used in transportation by 2000 and at least 30 percent of petroleum fuels projected to be consumed in 2010. However, as we discussed in a 2000 report, the act's strategy mandated purchasing of alternative fuel vehicles rather than targeting the use of alternative fuels.[8] We noted that since some of these vehicles also run on gasoline, drivers often used gasoline in these vehicles, either because they were unaware the car could run on an alternative fuel, or because not many refueling stations are available for alternative fuels. As you consider the FreedomCAR initiative, it is important to recognize, as was the case with the alternative fuel efforts, that there is a lack of infrastructure for fuels other than gasoline, as shown in figure 2. This lack of infrastructure could pose a significant challenge to the implementation of FreedomCAR if the vehicles it develops run on fuels other than gasoline.

[7] U.S. General Accounting Office, GAO/RCED-00-209R, *Observations on the Department of Energy's Fiscal Year 1999 Accountability Report and Fiscal Year 2000/2001 Performance Plans* (Washington, D.C.: Jun. 30, 2000).

[8] U.S. General Accounting Office, GAO/RCED-00-59, *Energy Policy Act of 1992: Limited Progress in Acquiring Alternative Fuel Vehicles and Reaching Fuel Goals* (Washington, D.C.: Feb. 11, 2000).

Figure 2: Density of Refueling Stations for Gasoline and Alternative Fuels, 1999



Note: Each dot represents 10 refueling stations in the state, rounded up to the next highest 10 (e.g., a geographic location of stations in the state.

Source: Energy Information Administration.

Even when an R&D program at the outset clearly defines where it wants to go and creates a logical strategy to get there, things often change along the way—new technologies develop, better approaches are found, and consumer tastes or needs change. As a result, those who manage R&D programs should consistently build in "reality checks" to ensure the strategy still helps to achieve the goals. Planners need to establish interim milestones that are meaningful, achievable, and can be reconsidered as the project progresses. For example, although the PNGV did not achieve its ultimate goal, the partnership did incorporate interim milestones that allowed it to reevaluate the progress of research efforts and reallocate spending towards the most promising technologies.[9]

Consider Whether Consumers Will Buy the Product

Research for its own sake can deliver basic scientific discovery and expand general human understanding, but to increase energy efficiency and reduce the reliance on oil, the FreedomCAR program must remain focused on developing technologies that are competitive in the marketplace. Unfortunately, in some of our work, we have seen that federal research sometimes produces compelling technical accomplishments, but few marketable products. In 1995, we reported that, although the U.S. Advanced Battery Consortium could potentially achieve its intermediate technical goals, the resulting batteries would be too expensive and would perform too poorly to enable electric cars equipped with them to be competitive with traditional automobiles.[10] In our report on the PNGV, we noted that the partnership developed some products that car manufacturers adopted into their existing vehicles. However, industry officials told us that consumers would probably not buy the vehicle the Partnership sought to create because the costs would be too high.[11]

In conclusion, Mr. Chairman, the FreedomCAR initiative's plan to develop fuel cell technologies represents an exciting area of research. Yet, based on our reviews of previous federal R&D initiatives, it will be critical for the initiative to keep one eye on achieving technical goals and one eye on the marketplace. Moreover, the ultimate success of the new FreedomCAR initiative should be judged by its contribution towards reducing the

[9] See GAO/RCED-00-81.

[10] U.S. General Accounting Office, GAO/RCED-95-234, *Electric Vehicles: Efforts to Complete Advanced Battery Development Will Require More Time and Funding* (Washington, D.C.: Aug. 17, 1995).

[11] See GAO/RCED-00-81.

nation's use of petroleum in transportation, rather than by reaching specific technical R&D goals.

Mr. Chairman this concludes my prepared remarks. We would be pleased to answer any questions you or any Members of the Subcommittee may have.

Contacts and Acknowledgements

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