THE HYDROGEN ENERGY ECONOMY

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND AIR QUALITY

OF THE

COMMITTEE ON ENERGY AND COMMERCE

HOUSE OF REPRESENTATIVES

ONE HUNDRED EIGHTH CONGRESS

FIRST SESSION

MAY 20, 2003

Serial No. 108–21

Printed for the use of the Committee on Energy and Commerce

Available via the World Wide Web: http://www.access.gpo.gov/congress/house

U.S. GOVERNMENT PRINTING OFFICE

87–487PDF WASHINGTON : 2003

For sale by the Superintendent of Documents, U.S. Government Printing Office
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THE HYDROGEN ENERGY ECONOMY

TUESDAY, MAY 20, 2003

HOUSE OF REPRESENTATIVES,
COMMITTEE ON ENERGY AND COMMERCE,
SUBCOMMITTEE ON ENERGY AND AIR QUALITY,
Washington, DC.

The subcommittee met, pursuant to notice, at 10 a.m., in room 2123, Rayburn House Office Building, Hon. Joe Barton (chairman) presiding.

Members present: Representatives Barton, Shimkus, Buyer, Bono, Otter, Wynn, Allen, Rush, and John.

Staff present: Bob Meyers, majority counsel; Kelly Zerzan, majority counsel; Andy Black, policy coordinator; Peter Kielty, legislative clerk; Bruce Harris, minority counsel; Jonathan J. Cordone, minority counsel; and Sue Sheridan, minority counsel.

Mr. BARTON. The Subcommittee on Energy and Air Quality is holding a hearing today on hydrogen and the potential for a hydrogen economy.

Without objection, we are going to proceed pursuant to Committee Rule 4E, which governs opening statements by members and the opportunity to defer them for extra questioning. Hearing no objection, prior to the recognition of the first witness for testimony, any member who, when recognized for an opening statement may defer his or her 3-minute opening statement and instead use those 3 minutes during the initial round of witness questioning.

Looks like we are going to be swamped with opening statements this morning. So the Chair is now going to recognize himself for an opening statement.

Today we are going to turn our attention to the future of hydrogen fuel cells, vehicles powered by hydrogen, and the hydrogen fueling infrastructure necessary to make it work. I want to thank my colleague, the Congressman from Maryland, the Honorable Albert Wynn, for encouraging a closer look at this topic. We have the same purpose of doing everything Congress can do to give hydrogen powered vehicles a chance to succeed.

It is amazing to contemplate the potential of millions of vehicles no longer needing conventional gasoline with emissions consistently near zero. H.R. 6, the Energy Policy Act of 2003, provides for a collaborative process between the Federal Government and the private sector. H.R. 6 foresees a fundamental decision by fueling companies and vehicle manufacturers by the year 2015 regarding having on-road vehicles and a fueling infrastructure deployed by 2020.

The 2020 deadline calls for cars to be acceptable to consumers in terms of price, performance, and safety. As we have learned with natural gas vehicles, a hydrogen fueling infrastructure must be pervasive and widespread in order for mass acceptance by consumers.

In his State of the Union address, President Bush envisioned a child born today having their first vehicle powered by hydrogen. I might say as an aside that since in Texas it is a Texas constitutional right that you get your first car at age 16, that we are going to have to move that up for children that are actually born today.

It may take that long because of the many technology improvements and cost reductions that must occur in addition to the development of thousands of new codes and standards. It may, indeed, take lessons from many years of stationary fuel cell applications before vehicles can succeed, and it may be that you cannot rush technology.

However, we do not want to delay the project until 2020 if it can be completed sooner than that. In fact, one of our witnesses, a gentleman from General Motors, may say that consumers could see this new product well before then if everything goes right.

During the subcommittee consideration of H.R. 6, Congressman Wynn offered an amendment to speed up the time table, require a Federal fleet mandate, and to authorize additional funding for stationary fuel cell demonstrations. I asked Congressman Wynn to withdraw his amendment, so that this subcommittee could more fully review the issues in the Wynn amendment. Today we are having that opportunity. I want to thank Congressman Wynn for working with us on this issue.

As we move toward the expected conference on energy with the other body, the lessons that we learn today will help us craft a hydrogen title that can achieve the vision that we all share.

We have before us witnesses from many of the different sectors that will play a role in the future of hydrogen fuel cells and energy infrastructure. Two of our witnesses can comment on barriers that this growing technology application will face in the real world. I want to welcome all of our witnesses today for their testimony.

At another hearing later in the summer, we are going to consider the broader issues relating to the future of energy production, where we will cover the potential for coal gasification, which could allow coal to produce electricity with fewer emissions and the possibility of carbon sequestration. We will also explore the administration's new future generation proposal, which could greatly improve our ability to produce hydrogen.

A decade or two from now, Americans may look back to this Congress as the time that we inspired a new generation of vehicles, a reduced reliance on imported oil, and a broad transition on a voluntary basis to produce the energy much more cleanly. When I fully retire from use my 1981 Buick Century station wagon, which I hope lasts at least half a century, you will know we, as a Nation, are headed in the right direction.

Now I would like to recognize Congressman Wynn for an opening statement.

Mr. WYNN. Thank you very much, Mr. Chairman. Before I begin, let me request that all members on the minority side be allowed to insert statements in the record by unanimous consent.

Mr. BARTON. Is that all members or just statements of the minority?

Mr. WYNN. Well——

Mr. BARTON. I think you said of the minority. Do you broaden that to say all members?

Mr. WYNN. I am happy to say that, to all members.

Mr. BARTON. Without objection, so ordered.

Mr. WYNN. Now, Mr. Chairman, let me say very sincerely that I thank you for calling this hearing. As you indicated when we were discussing H.R. 6, the issue of hydrogen fuel cells came up, and we talked about whether we were doing enough. You liked what we were doing, but you certainly wanted to hear more about it. I was very pleased at that, and I am even more excited and enthused that you have, in fact, called this hearing. I thank you for that.

I also want to note that there is a great deal of bipartisan support for the development of fuel cell technology. And if there are any partisan differences, it probably has to do with degree and certainly not purpose or intent of the initiative. The President's fuel car initiative provides $1.73 billion for the development of hydrogen fuel cell vehicles.

His initiative, which would provide money for research and development and demonstration projects, is a step in the right direction toward the development of commercially viable hydrogen fuel cell cars. Unfortunately, this plan would put hydrogen fuel cells on the road between 2020 and 2025 when the U.S. is over 70 percent dependent on foreign oil for its domestic oil consumption needs. I believe that we should make the vehicles commercially viable by 2015.

Today, stationary hydrogen fuel cells are a reality, providing backup electricity in some skyscrapers. Interestingly, the New York Police Department, Central Park Station, is powered by hydrogen fuel cells independent of the grid. In order to advance this technology, I believe that Congress should adopt a significant increase in Federal funding for the advancement of hydrogen fuel cell technology and the production and the fueling infrastructure needed to support the initiative.

I look forward to hearing from our industry witnesses who can talk about the challenges in developing affordable fuel cell vehicles and fuels.

As you mentioned, in April, I offered an amendment to provide $5.3 billion over 10 years for the advancement of hydrogen fuel technology. This program, like the FreedomCAR, would provide grants for research and development and allow corporations to apply for funding and demonstration programs.

By increasing funding and providing benchmarks for the rollout of the technology, the amendment would help make hydrogen fuel cell vehicles commercially viable around 2015. The things that I believe ought to be included would be elements such as research and development funds for hydrogen production, storage, and transport activities, as well as research and development funds for fuel cell technologies to develop more economically and environmentally sound fuel cells.

Also, we need a Department of Energy cost-sharing vehicle demonstration program to show the viability of fuel cell vehicles and widespread commercial use as well as cooperative agreements with the private sector to demonstrate fuel cell powered buses and trucks. The amendment that I offered would also include a demonstration project for stationary hydrogen fuel cells.

We would also require Federal Government agencies with motor vehicle fleets to collectively purchase 100,000 vehicles powered by fuel cells—the first phase of developing a commercially viable vehicle fuel cell program. In order to bring hydrogen fuel cells online in a way that makes the U.S. less dependent on the volatile world oil market, we must move forward with the fortitude of a Marshall Plan to bring hydrogen fuel cell vehicles online by 2015.

This not only requires additional funding but clear benchmarks as laid out in the amendment that I introduced for the technology to transition from stationary fuel cells to commercially viable vehicles within 15 years.

Let me conclude by saying again, thank you for holding this hearing, and I look forward to hearing from our witnesses this morning.

Mr. BARTON. Thank you, Congressman.

Seeing no other witnesses, we are going to start our hearing.

[Additional statements submitted for the record follow:]

PREPARED STATEMENT OF HON. MARY BONO, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA

Mr. Chairman, thank you for holding this important hearing today.

I am very grateful that you invited Catherine Rips from Sunline Transit Agency to testify. As you know, Sunline is located in California's 45th Congressional District and is a leader in this field.

President Bush has challenged Congress to move ahead with groundbreaking initiatives in hydrogen fuel cell technology. In this year's comprehensive energy bill, the House took the first steps in this direction by authorizing the President's FreedomCAR program and Hydrogen Fuel Initiative.

But we also need to work on refining other proposals. For instance, I understand the Administration has requested a total of $100 million for the Multi-Modal Research Program. However, these monies could thin out as they are split between fuel cells, the 21st Century Truck project as well as other programs. I would like to learn more from Ms. Rips, and other panelists, about suggestions on improving this program structure.

Another issue we must address is something that all alternative fuel initiatives must face, and that is building a reliable infrastructure. If we are to ever move from taking this technology beyond the public sector and into the garage of the average American, we must prepare to face this question now.

Again, Mr. Chairman, thank you for holding this hearing and I look forward to hearing today's testimony.

PREPARED STATEMENT OF HON. C.L. "BUTCH" OTTER, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF IDAHO

Thank you, Mr. Chairman.

Whether through the threats of rogue nations in the middle-east, the unreliability of OPEC, or the strikes of Venezuela, Americans have been all too often reminded of the threat our growing reliance on foreign oil poses to our economy and way of life.

Sadly, as the Clinton Administration sat by and watched, our nation's reliance on foreign oil grew steadily throughout the 1990's peaking at nearly 60 percent. Today, our nation's economy is a virtual hostage to the political and economic whims of the nation's that supply our oil. Hydrogen, however, offers us a promising domestic alternative to the uncertainty and manipulation of OPEC.

I am particularly interested in the idea of producing an abundant supply of hydrogen through the next generation of nuclear power reactors in our nation. I firmly believe that if our nation is going to meet its growing need for base-load electricity in the future, it will have to turn to nuclear power for the answer—and in that answer we will also find a source for hydrogen.

My home state is home to the Idaho National Engineering and Environmental Laboratory and Argonne National Laboratory West. These two facilities are on the cutting edge of nuclear power research and development and are poised to lead our nation's efforts to produce hydrogen from nuclear power. I've met with the engineers and scientists who work at these two world-class facilities, listened to their ideas and enthusiasm, and am convinced they're vision of combining nuclear reactors with hydrogen production makes undeniable sense.

Mr. Chairman, it's time our nation harnesses the intellectual strength and boundless ingenuity it possesses and ends its reliance on foreign oil. In doing so, we can look forward to a day when the power of OPEC and its oil is replaced by the security of a domestically-produced energy source like Hydrogen.

Again, thank you Mr. Chairman for holding today's hearing and I look forward to the testimony of the witnesses.

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

Last year, the Oversight and Investigations Subcommittee, under the leadership of Chairman Greenwood, examined several issues regarding the Department of Energy's "FreedomCar" program, which was first announced on January 9, 2002. That hearing examined several issues concerning the respective roles of the Department and the private sector in this new endeavor as well as its relationship to the previous Partnership for a New Generation of Vehicles, or PNGV program.

Today, the Energy and Air Quality Subcommittee expands the focus of this committee's review by looking not only at FreedomCar, but other efforts in the public and private sectors. As our first witness, Assistant Secretary David Garman, will testify, since the release of the Administration's National Energy Plan in May of 2001, three separate but related efforts have been announced: FreedomCar, the President's Hydrogen Fuel Initiative and, most recently, FutureGen, a program to develop a zero-emission coal-fired powerplant.

We cannot possibly address all issues and every aspect of these programs at this hearing. Instead, today we will focus on FreedomCar and the related Hydrogen Fuel Initiative. As our audience should know, both programs were authorized in H.R. 6, the comprehensive energy bill that was approved by the full House of Representatives on April 11th. Very broadly, this legislation provides for a set of twin commitments to occur in 2015 that will lead to the deployment of hydrogen fuel cell vehicles and the necessary hydrogen infrastructure in the year 2020.

I think it is important to understand, however, that a hydrogen energy economy is not limited to a fuel cell minivan pulling up to a hydrogen filling station in 2020, driven by a 16 year old (born today) who somehow managed to get the keys from mom and dad and who may have no intention of driving to the library like he promised. Instead, this new energy economy contains a massive set of interrelated efforts, which will extend throughout the fuel production, storage and distribution system and which will require a massive downstream retooling of industry and commitment of vast sums of private capital.

I think we all realize that this cannot occur in the blink of an eye. We cannot instantly change the course of industrial and transportation history that began roughly one hundred and forty-four years ago in Pennsylvania when the first commercial oil wells were drilled. Nor can we determine today how market forces will respond and shape the hydrogen energy economy in its real staging ground, the private marketplace.

But I think we can agree that there are important, vital questions concerning hydrogen energy for our country and for this Congress. And I look forward to our committee's continued examination and legislative work in this effort.

PREPARED STATEMENT OF HON. TOM ALLEN, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF MAINE

I would first like to thank the Chairman and our distinguished panelists for this important hearing. Mr. Garman, it is nice to see you again.

Hydrogen and fuel cell technology presents a potentially revolutionary technology for our nation, and we need to understand it here in Washington. This hearing will inform members about the policy choices presented by the current hydrogen debate.

Last month this committee passed a new energy bill that funded research and development of a fuel cell vehicle. It also created an incentive payment program in support of stationary advanced fuel cell distributed electricity generation. I hope our speakers will address this new legislation, whether it does enough to promote this technology, and whether it will lead to a commercial hydrogen vehicle market and a broader hydrogen based energy system.

I have supported hydrogen fuel cell development since I joined Congress. There is significant bipartisan support for this research. But the current bill allows industry to decide in 2015 whether or not to produce a fuel cell product. I am concerned that we will spend nearly $2 billion and end up with nothing to show for it.

Thank you all for coming. As this committee continues to consider energy policy, Members must be well informed about the real potential of a hydrogen economy.

PREPARED STATEMENT OF HON. SHERROD BROWN, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF OHIO

Thank you, Mr. Chairman, for scheduling this hearing, and thanks to our witnesses for what I expect will be informative testimony.

Thanks are also due our colleague, Mr. Wynn, for raising the issue of hydrogen technology commercialization during this committee's energy bill debate. As Mr. Wynn's amendment illustrated, it is well worth exploring whether and how we might bring hydrogen energy technology to the mass marketplace more quickly than the bill envisioned.

I would add that it is equally important to make sure that when we do bring this potentially revolutionary technology to market, we do it right. If we roll out vehicles and infrastructure that consumers cannot use or will not buy, we risk consigning a promising technology to the back bench. If we do not ensure that fuel production and use are environmentally sound, the new hydrogen economy will simply trade one set of problems for another. And if we focus exclusively on the development of hydrogen technology for only one mode of transportation, we risk undermining the transit systems upon which many of our constituents depend.

I am pleased to know that today's witnesses will discuss all of those important issues. Several witnesses will stress how indispensable it is to ensure that refueling options are widely available by the time hydrogen-powered vehicles hit the showrooms. As Mr. Garman and several of our stakeholder witnesses will also discuss, it is essential to ensure that the development and marketing of carbon sequestration technology is timed to dovetail with the vehicle and infrastructure technologies to ensure that fossil sources remain ecologically viable as sources of hydrogen. And as we will hear, public transit systems offer a number of advantages as laboratories for the commercialization of hydrogen energy technologies.

Let me take a moment to add my voice to the recommendation by Dr. Schwank for active university-based involvement in this effort. Fuel cell membrane research is one of several groundbreaking technology initiatives under development at the University of Akron's Polymer Center. That institution and other university-based programs offer not only technical expertise but also an independent perspective that will be invaluable as we work to ensure that hydrogen research is put to the best possible use.

I would also suggest that we consider an addition to the hydrogen provision included in the energy bill. Many of the research initiatives envisioned by that legislation would likely have applications for improved motor fuel economy in traditional gasoline-fueled vehicles. It may be worth doing more to promote the sharing of materials research and other technologies that could make a difference in environmental stewardship and energy security right now.

The notion of a federal leadership role in developing a hydrogen economy is rooted in the Partnership for a New Generation of Vehicles, established during the1990s. That program provided the foundation for substantial government investments in fuel cell research, as part of a broader effort to improve the energy efficiency of motor vehicles and the sustainability of America's transportation systems.

The challenge now is to build on that foundation, and today's hearing is an important step in that process. Additional hearings are necessary to ensure that the development and commercialization of hydrogen technology are advanced as quickly and effectively as possible.

I look forward to the testimony of our witnesses.

PREPARED STATEMENT OF HON. BOBBY L. RUSH, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF ILLINOIS

Thank you, Mr. Chairman, for holding today's hearing on the promising future of hydrogen energy and technology. Though the 108th Congress has legislatively addressed this issue in H.R. 6, the Energy Policy Act of 2003—by way of authorizing the FreedomCAR and Hydrogen Fuel Initiative programs—I believe it is useful for this subcommittee to follow-up and further deliberate on the prospects of a hydrogen-based economy; and to discern the obstacles to a full-fledged transformation down the road. The benefits of hydrogen energy are almost too good to be true: it is an abundant, efficient source of energy that has virtually no adverse environmental impact.

Having said that, and while I share my colleagues' optimism and enthusiasm on the benefits of hydrogen fuel technology, I also acknowledge the obvious fact that we are many, many years away from any sort of viable and commercial application of hydrogen energy. First, our nation lacks the fundamental infrastructure to produce, store and regulate hydrogen. Second, the commercial feasibility of hydrogen based products—such as hydrogen fuel cells—is still riddled with substantial cost-of-production and technological glitches.

I point out these obvious obstacles not to be a pessimist or cynic, but only to put things in perspective. While the Energy Policy Act is a solid attempt to speed along the transformation process, hydrogen energy remains a long-term solution to our energy needs. We can envision and boldly articulate a promising and distant future, but we mustn't lose track of our immediate problems in the present day. As such, Congress must continue to encourage the development of productive interim strategies and technologies that will serve as a bridge between our present fossil-fuel based economy and our future hydrogen-based economy. That is, in our enthusiasm to embrace the long-term, we must not lose sight of the short-term.

So thank you again, Mr. Chairman, for this oversight hearing on an exciting subject-matter, and I look forward to hearing the testimony of our panelists. I yield back the balance of my time.

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

Mr. Chairman, thank you for holding this hearing on a very important topic for the future of automobiles and American energy supplies. Hydrogen fuel cells will someday provide Americans with cars and trucks that produce few emissions and consume less fuel. As we will hear from our witnesses today, there is still much work to be done.

It is, however, an exciting time for the development of this technology. Earlier this month, the Chairman and CEO of General Motors brought a variety of impressive hydrogen powered vehicles to Washington. And just yesterday I was in Ann Arbor for the announcement of a new program sponsored by the Environmental Protection Agency (EPA), United Parcel Service (UPS), and Chrysler. The automaker will provide hydrogen powered delivery vehicles to UPS, and the EPA and Chrysler will monitor the real world issues that these vehicles will face, such as varying weather conditions and stop-and-go traffic. We must continue to encourage public-private partnerships that will lead to the widespread commercialization of this technology, making it available to all Americans.

While we continue to develop fuel cell technologies for the long-term, we must not forget the advanced vehicles we can produce in the near-term. With a little help, clean diesel vehicles and hybrid-electric vehicles can be widely available to consumers sooner than you may think. In particular, I want to help diesel technology along by improving the quality of diesel fuel and providing consumer incentives that will increase understanding and acceptance of this new technology. By significantly improving the fuel economy of the least efficient vehicles, clean diesel holds great promise for reducing our dependence on foreign oil in the near-term.

As we further the development of all advanced vehicles, we must make sure that American researchers, American manufacturers, and American workers are well equipped to produce these vehicles for the entire world. We must bring our universities into this collaborative process early and often. I note the attendance today of Dr. Schwank from the University of Michigan and Dr. Samuelsen from the University of California. They will have valuable insights into how we can use the resources of our academic institutions to develop this technology and produce the next generation of hydrogen scientists.

In addition to public-private partnerships, we must encourage our manufacturers to produce these advanced technologies here in the United States. We will not benefit if we shift from a dependence on foreign oil to a dependence on foreign technology and manufacturing. Grant programs and tax incentives should be provided to convert existing manufacturing facilities into advanced technology facilities. Encouraging the domestic development and production of hydrogen fuel cells and other advanced technologies will bring us one step closer to true energy independence.

Mr. BARTON. Our first witness representing the administration is the Honorable David Garman, who is the Assistant Secretary for Energy Efficiency and Renewable Energy in the Department of Energy. You have testified before this subcommittee before. We are glad to have you again. We are going to recognize you for such time as you may consume. Welcome to the subcommittee.

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

Mr. GARMAN. Thank you, Mr. Chairman and members of the committee. I appreciate this opportunity. And in keeping with the committee's letter of invitation, I will focus on FreedomCAR and the Hydrogen Fuel Initiative.

As the chart to your right shows, there is an imbalance between domestic oil production and transportation's demand for petroleum. This imbalance, now around 11 million barrels a day, is projected to keep growing. And we will not close this imbalance with regulation, new domestic production, or even both.

Although promoting efficiency in the use of oil and finding new domestic sources of oil are important short-term undertakings, over the long term, over the very long term, a petroleum-free option is eventually required. We ultimately want a transportation system that is free of dependence on foreign energy supplies and free of all harmful emissions.

But we also have to maintain and preserve the freedom of consumers to purchase the kind of vehicles they want to drive. That is the concept behind the FreedomCAR partnership and the President's Hydrogen Fuel Initiative, which are designed to develop the technologies necessary for hydrogen fuel cell vehicles and the infrastructure needed to support them.

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

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

Our current gasoline infrastructure has been forged over the last 100 years in a competitive market. It is remarkably efficient. It can deliver refined petroleum products that began as crude oil a half a world away to your neighborhood for less than the cost of milk, drinking water, or most other liquid products that you can buy at the supermarket.

We are currently bound to a petroleum infrastructure, and before drivers will purchase a fuel cell vehicle they have to have confidence in a hydrogen refueling infrastructure. That is why the President, in his State of the Union address, made a new national commitment backed over the next 5 years by $1.7 billion for the FreedomCAR partnership and Hydrogen Fuel Initiative.

Government is not going to build the hydrogen infrastructure. The private sector will do that as the business case becomes clear. But as we develop the technologies needed by the vehicles, we will also develop the technologies required by the infrastructure.

Some of the technology challenges we face are significant. For example, we must lower by a factor of four the cost of producing and delivering hydrogen. We also have to develop more compact, lightweight, lower-cost hydrogen storage systems. And we also have to lower by a factor of at least 10 the cost of materials for fuel cells themselves.

Fortunately, we are not starting from scratch. Beginning back in November 2001, DOE began working with industry, academia, the stakeholders on a comprehensive technology roadmap, and we have achieved a remarkable level of consensus on what needs to be done.

As important as hydrogen is for the long term, we have maintained a robust research and development program in non-hydrogen transportation technologies as well. Under the FreedomCAR partnership, we have proposed a funding increase in fiscal year 2004 for our hybrid technology as well as increases in materials technologies.

Many of these technologies will deliver fuel savings, both prior to and after the introduction of fuel cell vehicles, since lightweight materials and hybrid technologies will be incorporated into fuel cell vehicle designs as well as the conventional and hybrid models that precede them.

Auto makers are introducing the technologies that have resulted in part from DOE's work in this area in the past. At the recent Detroit auto show, the major U.S. auto makers announced that they would have a variety of new, hybrid gasoline electric models entering the market in the 2004 to 2008 timeframe.

Of course, hybrid vehicles are more expensive compared to conventional vehicles, which is why the President proposed a tax credit for hybrid vehicles in his national energy plan and in subsequent budget submissions, and we urge that Congress adopt this important incentive for more efficient vehicles.

Mr. Chairman, with that, I would like to end and ask that the rest of my testimony be entered into the record as if read, and would be pleased to answer any questions the committee may have, either now or in the future.

Thank you.

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

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

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

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

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

Since the release of the President's energy plan in May 2001, the President and Secretary Abraham have unveiled several exciting new initiatives related to hydrogen. Most notable are:

- The FreedomCAR partnership announced in January 2002;
- The President's Hydrogen Fuel Initiative announced during the State of the Union address in January 2003; and
- The "FutureGEN" zero-emission coal-fired electricity and hydrogen power plant initiative announced in February 2003.

Each of these initiatives plays a particularly important role in a hydrogen energy future. Each will help make possible a future in which the principal "energy carriers" are hydrogen and electricity, eventually generated using technologies that do not emit any pollutants or carbon dioxide.

Today, we are highly dependent on coal, natural gas and nuclear energy for the majority of our electricity. We depend on oil, a growing percentage of which is imported, to power our transportation needs. Through the FreedomCAR and Hydrogen Fuel Initiative we can eventually build a light duty transportation system that requires no petroleum, and is comprised of vehicles that emit nothing other than water vapor.

As illustrated in my first chart (Figure One) the "gap" between domestic production and transportation demand is growing—and is projected to keep growing. The current gap between total U.S. consumption and net production of oil is roughly 11 million barrels per day. Promoting efficiency in the use of oil, and finding new domestic sources of oil, are both important short-term undertakings. But over the long-term, a petroleum-free option is eventually required.

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

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

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

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

Our current gasoline/hydrocarbon infrastructure has been forged in a competitive market. It is ubiquitous and remarkably efficient. It can deliver refined petroleum products that began as crude oil half a world away to your neighborhood for less than the cost of milk, drinking water, or many other liquid products you can buy at the supermarket. We are currently bound to that infrastructure. Eventually replacing it with something different will be extremely challenging. But that is what we must do if we expect to achieve success with the FreedomCAR partnership. Drivers must be able to go anywhere in America and to refuel their hydrogen-powered vehicle before they will be comfortable purchasing one.

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

We will not build the infrastructure. The private sector will do that as the business case becomes clear. But as we develop the technologies needed by the vehicles, we will also develop the technologies required by the infrastructure. In cooperation with the U.S. Department of Transportation (DOT), we will convene the parties needed for technology partnerships, we will collaborate on the needed codes and standards, and we will promote international cooperation in this effort. On April 28, during a presentation to the International Energy Agency, Secretary Abraham called for an "International Partnership for the Hydrogen Economy" to collaborate on research and deployment of hydrogen technologies.

BENEFITS

Energy Diversity

Hydrogen can be supplied in large quantities from domestic fossil, nuclear and renewable resources. This mix of currently available and developing technology could provide a transition from traditional to next generation energy technologies benefiting society with reliable and affordable energy in the near and long terms. Hydrogen and fuel cells can catalyze the establishment and utilization of a viable transportation market for nuclear energy, domestic coal supplies, and renewables. Carbon capture and sequestration will be needed, however, for all carbon-based sources of hydrogen such as coal. The fact remains, though, that our Nation possesses the necessary resources to produce large quantities of hydrogen.

Transportation

Every day, eight million barrels of oil are required to fuel the over 200 million vehicles that constitute our light duty transportation fleet. By 2025, the Nation's light vehicle energy consumption is projected to grow to as much as 14 million barrels per day of petroleum or its energy equivalent. Fuel cell vehicles could provide more than twice the efficiency of conventional vehicles. Hydrogen fueled fuel cell vehicles could make dramatic reductions in petroleum use possibly resulting in 11 million barrels per day savings by 2040.

I would like to point out that the government does not have vehicle market penetration goals. The manufacture and marketing of hybrid, fuel cell or other advanced vehicles will be industry's responsibility. Instead, our plan lays out the activities that will accelerate hydrogen and fuel cell development to enable industry to make a commercialization decision by 2015. The government's role, however, can be broader than the removal of technical barriers and the reduction of technology costs. The government can also contribute to the pace of both industry and market acceptance by overcoming institutional barriers, such as those associated with achieving common codes and standards necessary for safe use of hydrogen and fuel cell technologies.

Fuel Cells for Stationary Power

Hydrogen can also be used in stationary fuel cells, engines and turbines to produce power and heat. In order to meet our growing electrical demands, it is estimated that electricity generation will have to increase by two percent per year (reference: DOE, Energy Information Administration, Annual Energy Outlook 2002). At this rate, 1.5 trillion kWh of additional electricity generation capacity will be needed by 2020. Along with aging infrastructure, requirements for reliable premium power, and market deregulation, this increasing demand opens the door for hydrogen power systems and potential societal benefits. For example, using ten million tons of hydrogen per year to provide 150 billion kWh of the Nation's electricity (just ten percent of the added generation) could avoid 20 million tons per year of carbon dioxide emissions. DOE will also support work in the area of fuel cells for portable power. While not important to overall petroleum reduction, these units will provide early operating and manufacturing experience, and should contribute to the reduction of fuel cell cost for polymer electrolyte membrane (PEM) fuel cells.

TECHNOLOGY CHALLENGES

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

Some of the significant hurdles to be cleared include:

- Lower by a factor of four the cost of producing and delivering hydrogen;

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

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

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

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

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

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

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

INTERIM STRATEGIES

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

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

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

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

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

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

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

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

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

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

TRANSITION TO A HYDROGEN ECONOMY

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

The FY 2004 budget currently before Congress is consistent with completion of the technology RD&D phase by 2015.

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

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

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

CONCLUSION

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

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

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

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

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

Figure 1: Oil Use in Transportation Plotted against Domestic Production

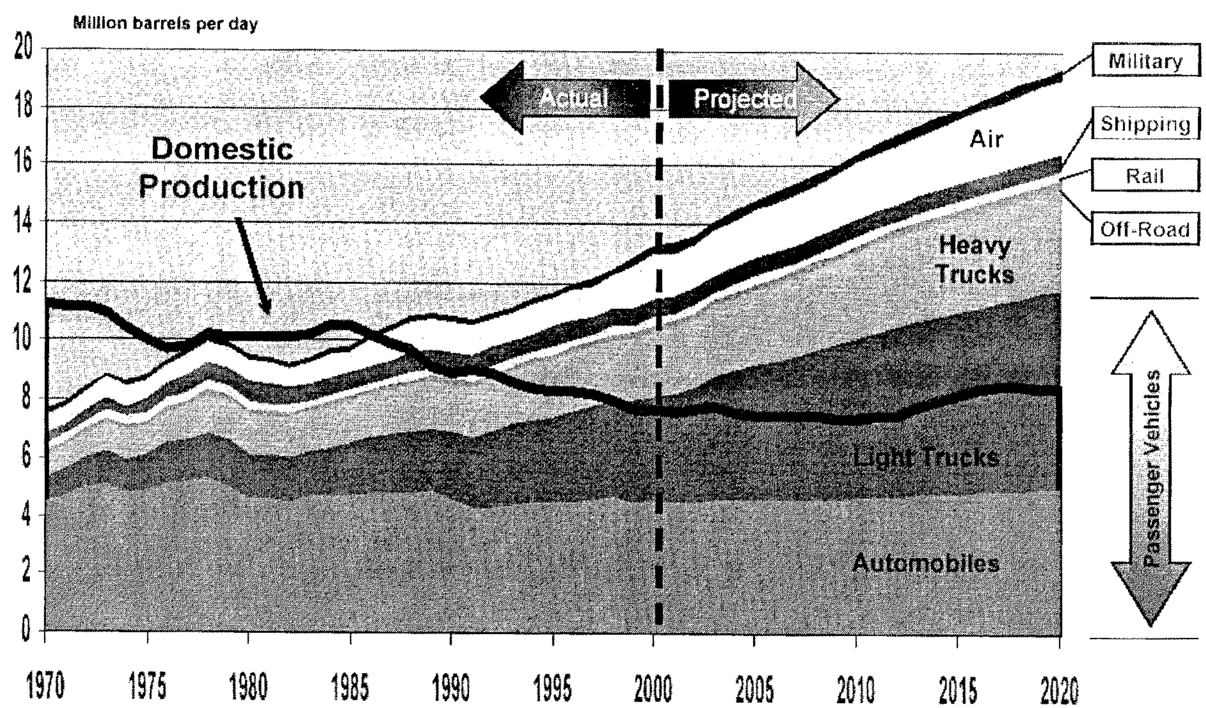
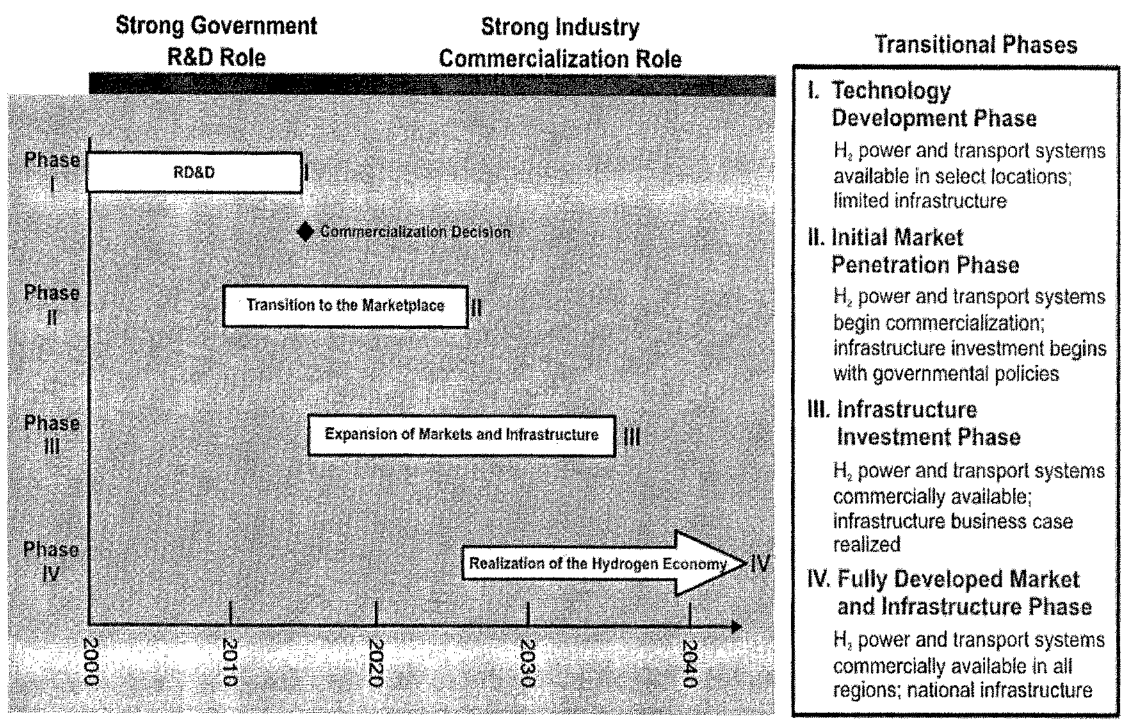


Figure 2: The Transition to the Hydrogen Economy



Mr. BARTON. Thank you, Mr. Secretary.

The Chair would recognize himself for the first 5 minutes, so we are going to use the clock for this. The first thing is, is the Department of Energy, under the President's hydrogen initiative, the lead agency in the administration?

Mr. GARMAN. Yes, sir.

Mr. BARTON. Which other cabinet agencies are involved in the initiative?

Mr. GARMAN. We will work very closely with the Department of Transportation, as they play a very critical role in terms of safety of vehicles, and certification of vehicles. We will work very closely with the Environmental Protection Agency. We will work with the Department of Commerce. There is a role for the NIST on standards and technology. And we think that all of this is going to be coordinated through our work and the work of the Office of Science and Technology Policy at the White House.

Mr. BARTON. What about the Environmental Protection Agency?

Mr. GARMAN. Absolutely. If I failed to mention them, they are a part of this effort as well.

Mr. BARTON. And the Department of Defense?

Mr. GARMAN. Yes, sir. Actually, I think both in stationary and transportation applications, as well as work in the heavy truck technologies. We have been a partner in the past with the Department of Defense, and we will continue to be a partner with DOD in the future.

Mr. BARTON. Within the Department of Energy, which Assistant Secretary has primary responsibility? I know that you kind of coordinate it, but which of the assistant secretaries is involved? Or if there is more than one, which ones?

Mr. GARMAN. Absolutely. We actually have a draft departmental posture plan under the guidance of the Undersecretary, Robert Card, for Energy, Science, and Environment. Under Mr. Card, the assistant secretaries or office directors that are involved in the hydrogen initiative include myself, the Office of Science, the Office of Nuclear Energy, the Office of Fossil Energy.

We are all working closely together on a coordinated plan, because, just as an example, the value of hydrogen is that it can be produced from diverse resources. And we want to make sure that we are leveraging our fossil resources, and our nuclear resources. We also have a great deal of synergy with the Office of Science doing basic research in such areas as microbes that actually produce hydrogen, or different types of material science that can really pay benefits in the work we are trying to do.

Mr. BARTON. How many different working group levels are there? Is there a senior policy level that you would participate in with the other cabinet agencies? And then, are there working groups at the professional SES staff level? And, you know, how often do they meet?

Mr. GARMAN. There is a couple of different working groups. The primary working group is run out of the White House and the Office of Science and Technology Policy. They have been meeting at least once a month, sometimes more frequently. I or members of my staff participate in that working group.

We also have, as an example, weekly meetings on international collaborations on hydrogen that occur in my office. Undersecretary Card has at least a quarterly review, and quite often more often than that.

Mr. BARTON. Do you feel that there is adequate coordination and organization within the Bush administration for this initiative? I mean, the President listed it as one of his priorities. Is it being given that type of preferential importance/emphasis in the administration, given the high priority the President gave it in his State of the Union address?

Mr. GARMAN. Yes, sir. I think that it has the almost-daily attention of the Secretary. We have worked very closely with Dr. Marburger at the White House, with the Council on Environmental Quality, Mr. Conniton, the Chairman of CEQ, on the policy coordination activities that usually the White House leads. We have not been lacking for resources or high-level attention to this at all.

Mr. BARTON. I have got time for probably one more question. The hydrogen that is produced today is primarily produced from natural gas using a steam reforming technology. Does the Bush administration have a preference on the source of hydrogen, or are you open to all kinds of sources?

Mr. GARMAN. Yes, sir. As you mentioned, virtually all of the hydrogen that we produce today is produced from natural gas. And the value of hydrogen, the fundamental value that we see, is that it can be produced from a variety of resources. That is what is so compelling about the hydrogen vision.

We would like to have a future where we have a multitude of resources and processes available to us that produce hydrogen. This can include renewables, of course. It can include nuclear energy. It can include fossil energy. It is—we have a vast supply of coal in this country. It is possible to do integrated combined cycle coal gasification.

Mr. BARTON. My time has expired.

Mr. GARMAN. Yes, sir.

Mr. BARTON. I don't want to cut you off, but my time has expired. But the basic position of the Bush administration on fuel source for hydrogen is open.

Mr. GARMAN. We are looking at all sources.

Mr. BARTON. Okay. My time has expired. I would recognize the gentleman from Maryland for 5 minutes.

Mr. WYNN. Thank you very much, Mr. Chairman, and thank you, Mr. Garman. I really appreciated your testimony.

A couple of questions. You state on page 4 that only $720 million is actually new money. Is that correct?

Mr. GARMAN. That is correct.

Mr. WYNN. Okay. I don't want to appear adversarial, but after all of the ballyhooing between the State of the Union and other speeches, are we really down to $720 million, this fuel cell initiative and FreedomCAR, beyond what we were going to do anyway?

Mr. GARMAN. The $720 million is above and beyond what we had planned to do in these programs anyway.

Mr. WYNN. Okay.

Mr. GARMAN. This is truly new money. And that is just over a 5-year commitment. We anticipate there will be a funding beyond that timeframe. We are just talking about the 5-year timeframe.

Mr. WYNN. At the risk of putting you on the spot, is it fair to say you could use more money?

Mr. GARMAN. The question is——

Mr. WYNN. If you answer no, I am going to be incredulous.

Mr. GARMAN. Well, actually, this is a question we are asked a lot. And the question is: Could you accelerate the timeframe if you were provided more money? And the answer is perhaps, but we would also increase the risk. There is a value of time in the discovery process and of research and demonstration that feeds back into the R&D.

Mr. WYNN. What is the risk?

Mr. GARMAN. For instance, if we were to have to actually field vehicles in the 2010 or 2015 timeframe, we would have to settle on some technologies very early that might not turn out to be the correct technologies.

Mr. WYNN. So your proposal would be to experiment with technologies over a period of time. Let me ask you a second question. Could you chart out a timeline for us? You've introduced a very interesting argument, which is we are going to have to have an experimental phase regarding the technologies. Could you chart out a timeline? How long is that phase likely to take?

Mr. GARMAN. Actually, I do have a chart. Jodi, if you could just flip that chart. This gives a notional timeline of—and you probably can't see that from there, but it——

Mr. BARTON. Do we have that on the big screen? Can we get it up on video? Because if we can, it is bigger.

Mr. WYNN. Since my time is running pretty rapidly, just give me a date. About how many years are we going to use to experiment with technologies?

Mr. GARMAN. Well, we expect to be in a position so that automakers and energy companies can make business decisions in 2015 to commercialize a vehicle. That means we are going to be trying demonstrations and activities prior to that time.

We actually have a 2010 goal for most of our key component technologies. We would like to be able to say that by 2010 we will have, if you will, broken the code on the key fundamental technologies that we have got in terms of the cost of fuel cells, hydrogen storage, and some of the other technology challenges we face.

Mr. WYNN. Okay.

Mr. GARMAN. Now, the business case sometimes takes a little longer.

Mr. WYNN. Okay. Let me move on. Between vehicle development and infrastructure development, can you tell us how these issues are prioritized, and what role will the Federal funding play in each? What role will Federal funding play, for example, in reducing the storage capacity requirements, lowering the cost factor for production, versus what contribution Federal funding will make toward infrastructure development? I guess which really is, storage is more infrastructure, and related infrastructure needs.

Mr. GARMAN. You have touched on a number of very important needs in all of these areas. I mean, I can give you some examples.

For example, in storage the technical challenge is storing enough hydrogen onboard the vehicle that gives the vehicle the kind of range that a consumer will require between refuelings.

And right now we don't have a technology that will enable enough hydrogen to be stored onboard the vehicle to deliver that kind of range. You want 300 to 350 miles before you need to refuel the vehicle.

For some technologies on solid metal hydride storage, chemical hydride storage, and other methods of storing hydrogen, including high pressure storage, more work needs to be done on materials to do that. Hydrogen is a very tricky material. You just can't put 10,000 psi in a metal cylinder, for instance, because the tiny size of the hydrogen will actually start migrating into the matrix of the metal. So you have some special challenges with hydrogen.

Mr. WYNN. About how long do you think it will take us to work through some of these infrastructure challenges?

Mr. GARMAN. It is difficult to foresee. We are certain—we think that in terms of the cost of fuel cells we see a path forward that doesn't require a big technology breakthrough. It just takes time.

On the issue of storage, we think we are probably going to need a technology breakthrough. There is going to have to be a discovery in a lab where somebody finds a hydride or another material that will store hydrogen, hopefully at ambient temperatures and pressures, and we don't have that today. And it is hard to put a timeline on a scientific discovery.

What we do want to do is to put the Federal funding out there, get the national labs involved, and make sure that different pathways are being explored fully.

Mr. WYNN. Thank you very much.

Mr. BARTON. We are going to do two rounds of questions for the administration witness, so the gentleman will have plenty of time to get in more questions.

The gentleman from Idaho is recognized for 5 minutes.

Mr. OTTER. Thank you, Mr. Chairman. Mr. Chairman, I had an opening statement, which I realize I—without objection, I would like that to be submitted into the record.

Mr. BARTON. It is already not objected to being put in the record.

Mr. OTTER. Assistant Secretary Garman, can you tell me how the hydrogen program is being coordinated between all of the various agencies that are going to be dealing with "energy and energy production"? For instance, the Office of Energy Efficiency, the Department of Energy. And, in particular, how the hydrogen budget is going to be handled by all of these varying agencies?

Mr. GARMAN. Let me start with the Department of Energy, and then I will move up. At the Department of Energy, we have a coordinated plan between my office, the Office of Energy Efficiency and Renewable Energy, the Office of Science, the Office of Fossil Energy, and the Office of Nuclear Energy. We all report to Undersecretary Card, who is playing the coordinating role in our hydrogen posture activities.

The Office of Energy Efficiency and Renewable Energy is sort of the subleader of this. We have the most money involved, and we do most of the work on both hydrogen production and the vehicle technology work. But we are very well coordinated. We have a posture group that meets frequently.

Above the Department of Energy in ensuring coordination with other Federal agencies, of course, are the White House groups, the Office of Science and Technology Policy, and the Council on Environmental Quality. They are both exercising a policy coordinating role, as is the Council of Economic Advisors out of which a lot of domestic policy derives from the White House.

We have a very tight and close group. We are in nearly constant communication, and that is how the general policy effort is coordinated.

Mr. OTTER. Mr. Secretary, who is the boss? Where does the buck stop?

Mr. GARMAN. I think the buck stops primarily with Secretary Abraham. Secretary Abraham looks to me and Undersecretary Card, because the way this initiative was developed included a lot of policy time with the President. And the Secretary laid this out for the President, and I think the President looks to the Secretary to deliver on the promises and the assurances that the President was given.

Mr. OTTER. Well, you know, I appreciate the high level of folks that are involved in this. But as you know, the grunts are the ones that are going to do the work, and they are the ones that are also going to come up with the problems, and the resolution of those problems has got to be fairly fast in order for a program that is this important and holds this much promise for us to be able to go forward.

And has there been any scheme or any notion presented where that is all coordinated in just one office and put in one office, and all of the answers come from that office, and all of the coordination comes from that office?

So many times I have found—and I appreciate the fact that I have only been here for 3 years now, or less than 3 years—but so many times it seems to me when you go to one agency that is supposed to have the responsibility for coordination between some government program you end up with, “Well, that is not in our pay grade, and that is not our responsibility.”

I think that this is way too important to us for energy self-sufficiency and also for energy independence for us to scatter amongst the many bureaus and departments and not have one place that we can go to and say, “You are simply not doing the job. You are going to be replaced.”

Now, I have met with Secretary Card, and I think he is doing a tremendous job. And I love his enthusiasm for the hope and for where he wants to go, and especially, of course, for my part being from Idaho where the Argonne National Laboratory is, I hope, going to play, could play, will play a major role in this.

But on the other hand, I have seen so many times where we spend a lot of money, we get a lot of motion, and precious little progress. And I would just hate to see it scattered so far and wide that nobody knows where the hell to go to surrender when they have got a problem.

Mr. GARMAN. I think there is a couple of things that we have working for us in this regard. First of all, and this is part of the

President's management agenda and the importance that he places on linking budget and performance, we have set very specific technology goals that are measurable and for the achievement of which we are accountable.

These technology goals for FreedomCAR can be understood, they can be measured, and our performance against those goals—these are expressed in terms of 2010, what we want to achieve between now and 2010—can be evaluated on how well we are doing, where we are falling behind, and where we are ahead.

We expect, because this is a high level Presidential initiative, we expect to be subjected to scrutiny, not only by the White House but the Congress on a regular basis on how we are achieving these goals. And we welcome that scrutiny, and we think we are up to the task.

Mr. OTTER. Thank you.

Thank you, Mr. Chairman.

Mr. BARTON. Thank you.

The gentleman from Louisiana is recognized for 5 minutes.

Mr. JOHN. Thank you, Mr. Chairman, for holding this hearing. And I want to thank the Assistant Secretary for coming and starting off a debate on an issue that is really going to be critical to the future of America.

I want to follow up on a line of questioning from the chairman as it relates to the feedstock issue. You had mentioned in your last remarks to the chairman, that the Bush administration is open, because it is intriguing, in your own words, to the variety of options that we have to produce hydrogen.

And as I look down, there are several things that I notice. First of all, I am a firm believer that money follows priorities in this body in Congress and really everywhere we go. And if you look at the fiscal year 2004 and the administration request, I think it itemizes and prioritizes the different types of feedstock by placing dollars in different kinds of feedstock.

If you look at them, of course, nuclear is $4 million, coal is $5 million, natural gas is $2.2 million, and, of course, renewables is $17.3-.

Mr. GARMAN. Actually, $12.2. If——

Mr. JOHN. $12.2. What did I say? I am sorry.

Mr. GARMAN. $2.2. I am sorry.

Mr. JOHN. I am sorry. Yes, I have it written. I just didn't say it correctly. So I think that that kind of gives us an indication of where we want to put our emphasis on technologies on research.

What I would like for you to do is to talk to me a little bit about the economies of each one of those, and then we will talk about the challenges of each one of those, and then try to end in my 5 minutes about, why you believe that, over $10 million was put in renewables as opposed to nuclear, coal, or something else.

Mr. GARMAN. Part of the reason that you see that split is in part because government likes to—and it is more appropriate that we engage in very long-term R&D. If you want a fully sustainable energy system, you would like over the long term to be able to depend on renewables and have renewables the basis of your hydrogen production.

Mr. JOHN. And I agree with that. And while we are there, help educate me on the renewables. What is the renewable feedstock of choice for a variety of reasons?

Mr. GARMAN. One method is simply using electrolysis from a renewable produced electricity—for instance, wind power—producing electricity from which you use electrolysis to split the water. That is one process. You can use any form of electricity to do advanced electrolysis.

Another is gasifying biomass. Were we to have, for instance, 600 million metric tons a year of biomass, that could take the form of corn stove or wheat straw, different kinds of things that farmers generally leave in the field today.

Mr. JOHN. Rice hulls?

Mr. GARMAN. Rice hulls, you name it. And we can convert that, gasify that. That is also a hydrogen source. We are hoping that we can, for instance, get the price of biomass down to around $2.60 a kilogram in terms of the cost of the hydrogen produced from the biomass. That will depend on a number of things, but that is, for instance, a kind of notional 2010 target that we have in mind.

We have to do a lot better than that. A kilogram of hydrogen is roughly equivalent to a gallon of gasoline. So $2.60 gasoline doesn't quite cut it for us.

Mr. JOHN. Okay. We only have about a minute. Talk to me about the economies of each one of those.

Mr. GARMAN. Sure.

Mr. JOHN. I mean, good, bad, challenging, not there?

Mr. GARMAN. As I said, biomass via gasification we think we can get by 2010 in for $2.60 per kilogram. Advanced electrolysis, we think by 2010 maybe we can get close to $2.50 a kilogram. Solar high temperature thermochemical cycles, that is where we use very high temperatures, on the order of 1,000 degrees Centigrade, using high temperature and a chemical cycle to split water. That is relatively expensive. We think that is probably around $4 a kilogram.

In theory, if we have a high temperature gas reactor, which we do not have in this country, you could use that same heat offput from a high temperature gas reactor to do the same thing—thermochemical water-splitting. Theoretically, we think we can get around $2 a kilogram with that approach.

There are other approaches, including something we call photolytic. It is very long term. It uses photons directly from the sun, kind of like a solar cell, but instead of converting the photons to electricity and then using the electricity to make hydrogen, the conversion is direct. We think we are probably above $20 a kilogram in that area. But it still is a long-term play, if you will.

Natural gas, we think we can get natural gas derived hydrogen down to $1.50 per kilogram in 2010. It is currently around $5 or $6.

Mr. JOHN. If you could—Mr. Chairman, I would like to maybe ask for an additional minute, so we can get through this, or should we wait until the next round?

Mr. BARTON. No, go ahead.

Mr. JOHN. Okay. I would like to ask for another minute and a half.

Mr. BARTON. Without objection, let us give you 2 more minutes.

Mr. JOHN. Okay. Thank you.
Mr. BARTON. When the clock gets to——
Mr. JOHN. This is very——
Mr. BARTON. When the clock gets to three. How about that?
Mr. JOHN. That is fine.
Mr. BARTON. All right.
Mr. JOHN. Thank you, Mr. Chairman.

Mr. GARMAN. Natural gas we think is the near-term supplier for a couple of reasons. First of all, we make around 9 million metric tons of hydrogen each year today for a variety of purposes. We need 40 million metric tons to fuel a fleet of about 100 million vehicles, and we are already making 9 million metric tons.

Natural gas has an advantage in that we already have a distribution system in place that is delivering the natural gas to fueling stations and locations all over the country. We have already demonstrated the fact that we can take natural gas at a fueling station, convert it to hydrogen, run a stationary fuel cell, and store the hydrogen to fuel vehicles. We have such a station in Las Vegas.

We have other stations in California and elsewhere, where we are demonstrating this technology today. So we know that works, and we know that that is one pathway for a near-term hydrogen infrastructure that won't depend on large central manufacture of hydrogen and dedicated hydrogen pipelines.

Over the long term, we will probably want to achieve the economies of scale possible from central large manufacture and production of hydrogen and the use of hydrogen pipelines. So that is the thinking—near term, natural gas; long term, diverse resources.

Mr. JOHN. Okay. We are out of time. I would like to continue this maybe in the next round of questions.

Thank you, Mr. Chairman.

Mr. BARTON. Thank you.

Does the gentleman from Indiana, Mr. Buyer, wish to ask questions?

Mr. BUYER. I have one I was thinking about on a safety—from the safety standpoint. Some years back, there were some workers in the shuttle program—when the shuttle had returned, they went in and they were doing an inspection. The worker collapses. The second worker goes in really concerned, and then he collapses. They both died. And as it turns out, it was a hydrogen—some leakage.

I have always remembered that, because how awful that must have been if it was a small quantity, and they didn't know, and, bang, it got them. So from a safety standpoint, could you talk about that, if you have leakage and at what quantities? If that is part of the considerations? Obviously, it should be.

Mr. GARMAN. Absolutely. And the real safety concern with hydrogen is not toxicity. It is flammability. But there is also an advantage of hydrogen, which makes this not a great concern. I think those NASA workers that you spoke of probably encountered this hydrogen in a very enclosed space where it was highly concentrated, and the real danger to them is it displaced the oxygen that they would normally have available.

Hydrogen is the lightest element on the periodic table, and, as a consequence, you will not find free hydrogen on the planet anywhere. It is always bound up in a compound, such as water or coal or some hydrocarbon or some other chemical. And the reason is, it is so lightweight it can actually escape the gravitational pull of the earth.

So when you do have a release of hydrogen, it dissipates very quickly and disperses, and that minimizes any problem you would have such as the NASA workers, and it also minimizes the problem inherent of its flammability. Like any fuel, hydrogen has a high energy content. It is flammable, but——

Mr. BUYER. Well, let us break it down to—I am Bubba, okay? I don't work with this compound. So with NASA workers obviously going into a tank that is a closed, confined area, leakage—you can understand perhaps why they died.

Now we are advanced in the future, and I have got my fuel cell automobile, and we go in to have it refueled. Is that something that you envision somebody else doing?

Mr. GARMAN. No, sir.

Mr. BUYER. Or is that something that I could do on my own?

Mr. GARMAN. You would do it on your own.

Mr. BUYER. And if there were some kind of leakage or if—or even from—say you had an auto accident, and it began to leak. You don't anticipate any problems?

Mr. GARMAN. Not from a toxicity standpoint. In fact, because we are so attuned to safety and ensuring that there is no leakage of hydrogen, either on board the vehicle or during the refueling process, every hydrogen vehicle you see today has a very sensitive and redundant system to detect hydrogen leaks and alert the driver if they do exist. And, again, your concern is not so much toxicity but flammability.

Mr. BUYER. All right.

Mr. GARMAN. And in that, were you to have an accident in a hydrogen vehicle, I think you actually have an advantage over a gasoline vehicle, and here is why. Should you have a breach in the hydrogen container, the hydrogen being far lighter than air is going to move up and away from the vehicle.

Contrast that with the situation you have when you have an accident in a gasoline vehicle. If you have a breach in the tank, the gasoline spreads below the vehicle. And, of course, if it engulfs, it engulfs the vehicle and its occupants. So I think I would rather drive my family in a hydrogen vehicle than a gasoline vehicle, and the safety issues are—while very serious, something that we and the Department of Transportation will be taking a close look at.

Mr. BUYER. Let me ask this, switching gears. When you close your eyes and you try to envision what the future may be, how do we here in Congress ensure that the marketplace is open, fair, and competitive, when we try to eliminate these vertical integrations that could possibly occur? How do you envision the marketplace?

Mr. GARMAN. I think we have to look——

Mr. BUYER. And when I say that, competitively in infrastructure as well as others.

Mr. GARMAN. We are in the process right now of inviting major vertically integrated oil companies, if you will. They usually don't refer to themselves that way anymore. They start to refer to themselves as energy companies now, because they realize the hydrogen age is coming, and they want to be in a position not only to sell you the gasoline you buy in your vehicle, or the Slurpee that you go in and get when you go in and buy your gas, but they also want to be the ones to provide you with the hydrogen or whatever it is going to take to fuel your vehicle.

That is the business they are in, so they are engaged with us. They are working with us. They are excited about this possibility. And if we don't use market forces to help make this transition, then we are really missing out on the greatest force for change that we have available to us.

The reason that I think the hydrogen economy and hydrogen vehicles are going to come about is not only because of the commitment the President made, it is because it is going to make available to consumers a better car than the kind of car they can buy today, which has advantages that the car today that they have can't provide.

That is going to be an intriguing market driver, and I think that is what we want to take advantage of. It is a little bit like the government's involvement in the creation of the internet. We created the basic technology, and we developed standards and protocols, but it was the market that built the internet, driven by consumer demand and consumer dollars. And I see the hydrogen infrastructure operating very similarly to that.

Mr. BUYER. Thank you.

Mr. BARTON. The gentleman from Maine is recognized for 5 minutes for questions.

Mr. ALLEN. Thank you, Mr. Chairman.

And thank you, Mr. Garman, for being here. This is an interesting and important subject.

I wanted to come back to, you know, where the fuel comes from. Is there something called the national hydrogen energy roadmap?

Mr. GARMAN. Yes, there is.

Mr. ALLEN. Yes. And is that prepared by the administration?

Mr. GARMAN. This is a copy of the roadmap, and I will be happy to provide it to you or for the staff for the record, however you want it. It was prepared, actually, by a couple hundred folks. The administration convened it, but we invited everyone from Exxon Mobil to the National Resources Defense Council to come and gather in a room and start to think about the technology challenges and the technology roadmap we needed to develop.

Mr. ALLEN. I haven't seen the whole thing, but I was told that in the roadmap 90 percent—the plan is, at least in that document, for 90 percent of all the hydrogen for this program to be refined from oil, natural gas, and other fossil fuels, with the remaining 10 percent cracked from water using nuclear energy. Is that an inaccurate statement or——

Mr. GARMAN. The reason that that would be a difficult statement is it depends on the timeframe.

Mr. ALLEN. Yes. Well, the near term—I take what you say and accept what you say about the near term, that natural gas is the only logical place to get hydrogen. But one of my questions is—the long term is harder to predict. And in particular, natural gas is now the fuel of choice for our electric utilities.

And when I talk to people in the energy industry, at least some of them, you know, are concerned about the long-term supply. If basically both our electric generation and our automobiles are going to be—ultimately go back to, you know, another fossil fuel to be sure of the cleanest fossil fuel, natural gas, but that has—there is a question about, you know, how much of it is there over the long term, and also what the price will be, because part of the goal here to make a hydrogen car affordable has a lot to do with whatever the market price happens to be.

Would you mind making just a couple of comments on that pricing issue and how we can—and just if you could add in one thing. As I understand the program that we passed, there is really no requirement that Detroit ever put a vehicle on the road. I mean, this is all a research project essentially.

Mr. GARMAN. Okay. First of all, with respect to availability, we believe that there are a variety of methods that we have available to us to make sufficient amounts of hydrogen. And I will just give you an example. If, as a Nation, we made a determination that we wanted to make 40 million metric tons of hydrogen, enough to fuel a fleet of 100 million vehicles, and we wanted to make it solely from wind power, we could do it with the wind capacity of the State of North Dakota alone.

That is a possibility. I am not sure that the market would evolve that way, but that is a possibility, and it illustrates the fact that we have a diverse amount of resources that can produce the necessary hydrogen that we need.

So availability we think is there. If we can get the technologies to produce wind power at an affordable price, we would have very affordable power, and wind power has been getting more and more and more competitive. And so I am bullish, as a long-term play, on hydrogen from wind-generated electrolysis. I think there is something in that, and I think we can do it, and I think we as a Nation have the capacity to do it.

On the question of price—price is, of course, a driver. I went through some of the numbers a little bit earlier. The thing you do have to remember is that because a fuel cell vehicle is 2 to 3 times more efficient than a gasoline vehicle, you will get more work out of an equivalent amount of hydrogen than you do gasoline.

Mr. ALLEN. If I could just follow that—relate that to the car I drove to New York this weekend. I drove to New York from Portland, Maine, and back this weekend, 550 miles. I got 48 miles to the gallon. I was in a Toyota Prius that I own that I bought because I couldn't buy a hybrid from Detroit.

And I know that the emissions from that car are about 10 percent, I think, of the emissions from the, you know, ordinary new car on the road. How does that hybrid technology, which is already there for people who want to buy it in this country, relate to this hydrogen project? And if you can, say why the administration didn't do more. I know there are incentives, but why not do more to encourage hybrid technology?

Mr. GARMAN. That is a terrific question, and I want to start, as a Prius owner myself—point out that I am a huge believer, and we are a huge believer in hybrid technology. That is why the President asked for a tax credit for purchasers of hybrid vehicles, in order to help promote that technology. And it is a great near-term technology.

Over the long term, the total system efficiency of a fuel cell vehicle is much, much greater than that of even a gasoline hybrid electric vehicle, even when you take into account the energy inputs you have to make to make the hydrogen, and compress the hydrogen. I am talking about a total well-to-wheels efficiency number.

A gasoline hybrid electric vehicle, on a well-to-wheels basis, is 15 percent efficient. That includes the efficiency of the fuel chain and the vehicle itself.

A fuel cell vehicle fueled with hydrogen produced from natural gas is 22 percent efficient, and that includes the energy inputs you need to create the hydrogen, compress it, and the rest. So that is a huge efficiency increase that can't be denied.

And the great thing about hybrid technology is that it is a pretty good bet that you will employ hybrid technology in a future fuel cell vehicle as well, so that you will hybridize that vehicle. And most of the fuel cell vehicles we drive today are hybridized to give the drivability that you want.

Mr. ALLEN. Thank you very much.

Mr. BARTON. The gentlelady from California is recognized for 5 minutes.

Ms. BONO. Thank you, Mr. Chairman. I actually have no questions at this time. I just want to thank the Secretary for all of your hard work, and your staff as well, and I look forward to working with you. And I yield back.

Mr. BARTON. The gentleman from Illinois, Mr. Rush, is recognized for 5 minutes.

Mr. RUSH. Thank you, Mr. Chairman.

Mr. Garman, this question might have been asked and answered in my absence, but I want to try to get to it again if it has been. Implicit in any government subsidy is the assumption that unfettered market forces alone is inadequate—they cannot inadequately achieve public good or outcome.

In other words, by investing $1.7 billion over 5 years for FreedomCAR and for hydrogen fuel initiative programs, we in the Congress assume that the private sector alone was incapable of developing a hydrogen-based fuel economy. Can you tell us exactly how DOE will use these funds, this $1.7 billion, over the next 5 years to overcome natural private sector market barriers that exist to developing hydrogen energy?

Mr. GARMAN. Yes. And we will be doing work on—in a variety of different areas, including production and delivery of hydrogen. Let me back up a little bit. Right now, as you point out, there is not a financial incentive for General Motors, for instance, to build a fuel cell car, or Exxon Mobil, for instance, to put hydrogen in at the corner filling station.

There are some terrific public benefits that could be garnered—lower dependence on petroleum, cleaner air, but those benefits are not monetized in the marketplace, such that consumers would pay for them or that people would make money delivering that benefit.

As a consequence, we believe that we can apply R&D activities in a few key areas, including production and delivery, storage, safety codes, standards, utilizations, technology validation. We are going to have to do some demonstrations to demonstrate the technology. Some of these demonstrations are occurring today at small levels, such as, in California, SunLine Transit.

What we need to do is to scale these up a bit, put more cars on the road, understand what the shortcomings are, feed back into the R&D activity to address those shortcomings, and get the confidence that we need that the fuel cell vehicle can be as good as, and, in fact, better, than the vehicles that consumers can choose and drive today, because ultimately, you know, we are focused like a laser beam on that consumer choice test that will confront all of us in the 2015/2020 timeframe.

We have tried different mandates and formulas and incentives in the past, but at the end of the day if you really want this technology to succeed, you have to offer the consumer something better than they can drive today. And that is part of our thinking. We think that there is a benefit for automakers with this technology, and there are benefits for consumers that will drive both automakers and consumers in this direction.

Mr. RUSH. It seems as though this—and a hydrogen-based economy is at least some decades away. And in the meantime, we have to face pragmatically our various energy needs, and we have to face them in an innovative and creative way. And what is DOE doing in the interim to bridge the gap between the fossil fuel-based economy and the hydrogen-based economy?

Mr. GARMAN. Well, the most inexpensive way of reducing energy use is to make current energy use more efficient. And that is the primary goal, if you will, of my office in DOE, and we spend more money on enhancing energy efficiency, through the weatherization program, through vehicle technologies programs, through partnerships with industries, and a whole host of other programs, than we do on anything else in my office, because efficiency—improving the efficiency of current use is job one.

And I think that is reflected in the work of this committee in the energy bill. So I think in the short term the answer is efficiency. That is your quickest and cheapest way to reduce the demands of energy use on the environment and our pocketbooks.

Mr. RUSH. Thank you, Mr. Chairman. I yield back.

Mr. BARTON. Thank you. The other gentleman from Illinois, Mr. Shimkus, is recognized for 5 minutes.

Mr. SHIMKUS. Thank you, Mr. Chair, and I apologize for being late. But this is a great hearing, and, of course, this is something my friend from Maine and I have discussed ad nauseam at different forums. But I think the thing—even though there are sometimes things that separate us, I think what unites us is this is exciting, and we—the sooner we can get here, the better.

I would also be interested in getting a copy of the national hydrogen energy roadmap, because a lot of discussion will be about, you know, the fuel. Since I am a conservative, market-driven individual, instead of the government eventually trying to pick winners and losers on the fuel, what we—I think what would be best to do is to set the standards and allow the different—the market force to then move to produce the best competitive fuel for the particular use.

I always talk about natural gas quite a bit, because natural gas, I don't think, is a choice for most electricity generators. It is a higher cost, and we use it for peaking. We use—for the most part in this country use coal. We use nuclear. We use a lot of options. In the midwest, natural gas is best used for home heating. That is not true in the northeast, but it is probably the most efficient way to use natural gas.

When we, as a government, try to distill policies to pick winners and losers on the commodity end, we, in essence, disenfranchise all of the other folks out there. So that is why I am interested in the energy roadmap and what has been discussed about the possible input fuel.

I know there is great research going on at Southern Illinois University at Carbondale with coal and the production of hydrogen from that fossil fuel, which we find is exciting. I will be also interested in biomass issues with—of course, with my focus on corn and soybeans, which is no surprise of my chairman here.

But we want to make sure that as we move to this that all of the input, the commodities, are given a goal, and then we allow technology to flow in that direction to let the market choose the best fuel for the best use, which will also allow us to—for the best fuel for the best use in other arenas, whether that is home heating or whether that is electricity generation. That is this whole reason why we have the big energy debate that we have to some extent. So I just wanted to get that on the record.

We also are excited about—and I know we have got panelists in the next group with what will be planned here with the cars and the fueling station with the Shell consortium and GM, which has a real world application upfront, close and personal.

I don't think my three boys who are growing and our luggage will fit in the Prius on a drive from Maine to Washington, DC. But I think there are some hydrogen vans that I observed that might be able to fit us all in there, which, again, just lends itself to the great opportunities for the future.

I guess the biggest hurdle and the question I have had is the—and you have probably addressed it, and I apologize if you have—but obviously, for that fueling station to be placed on the hill, there is going to be concern—first of all, there would be the concern of the cost for the individual, and you had mentioned that a little bit also. It was in the tail end on the security issues from my colleague from Indiana.

How do we go about alleviating those fears and concerns? And how do we incentivize the placement of infrastructure to provide the fueling stations for this new technology?

Mr. GARMAN. The cost and the safety and the security aspects are part of our research, development, and demonstration activities now. We actually just put a competitive solicitation on the street offering up to $150 million in cost-shared activities related to demonstration and technology validation, to actually get cars and stations on the road in prototype, in different geographical areas, so that we can see what works, what doesn't work, how to drive the costs down.

We have already done a little bit of work. We probably have, what, 10 or 15 hydrogen refueling stations in the country now. In each one we make more and more improvement in lowering the cost. That is indeed very important.

In terms of incentives, I think it is too early to talk about incentivizing the placement of fueling stations in a market setting, because, frankly, we want to make some progress on the technology.

But Congress, in its wisdom at some point, says, "Well, let us do a production tax incentive, or a tax credit to incentivize." But we are not there yet on the hydrogen vehicles or the infrastructure. When the technology and the costs get in the ballpark, then I think it is ripe to start talking about how we incentivize the placement.

Mr. BARTON. The gentleman's time has expired.

We are going to start our second and last round of questions for the administration witness, and the Chair is going to recognize himself.

I am going to feed on what—a little bit what Congressman John was asking and Congressman Allen, and also Congressman Shimkus. I want to try to get some definition on the base case model or the base case goals for the efficiency or the cost of hydrogen.

In my congressional district, my town meeting reference case for cost of gasoline is somewhere between $1 a gallon and $1.25 a gallon. When gasoline is at that price level, I don't have too many complaints. But when it gets above it, you know, my town meeting reference model people start, "Congressman, what are you doing about the cost of gasoline?"

So is there a goal for the reference case of what the equivalent cost per whatever of hydrogen should be to make it accepted in the marketplace as you were talking to Congressman Allen? And what is the unit of measure? Is it—you said kilogram. Is it kilogram? Is it MM BTU? Is it—you know, who knows? What are we—if the Congress set a target to the administration, "We want fuel cells, hydrogen mobile source fuel cells for cars and trucks, to cost no more than the equivalent cost of, say, $1.50 a gallon gasoline," what would that be?

Mr. GARMAN. You have just expressed our 2010 R&D goal for the cost of hydrogen from natural gas. Our published FreedomCar goal is $1.50 per gallon of gas equivalent.

Mr. BARTON. And what is that in hydrogen?

Mr. GARMAN. It is roughly a kilogram.

Mr. BARTON. So you want hydrogen to be no more than $1.50 per kilogram.

Mr. GARMAN. Roughly. And that is untaxed. We haven't talked about taxing.

Mr. BARTON. We don't allow any talk about taxing in this subcommittee.

Mr. GARMAN. Very good, sir. I won't get into that, then.

Mr. BARTON. This is not the Ways and Means Committee.

Mr. GARMAN. But our R&D goal for 2010 is $1.50 per gallon of gas equivalent from natural gas.

Mr. BARTON. And is there—again, when you were referring to Congressman John, he kind of led you through the different sources and their costs. Is there any reason to believe that some of the non-conventional sources of hydrogen, i.e., you know, some of the renewables and perhaps even nuclear, can they get to that level? Is there any reason to believe they can't with enough technology research?

Mr. GARMAN. I don't think they can get to that level by 2010.

Mr. BARTON. But at some point in time.

Mr. GARMAN. At some point, breakthroughs make a multitude of things possible.

Mr. BARTON. So you see a transition starting with natural gas as the choice of fuel to get to hydrogen.

Mr. GARMAN. Yes.

Mr. BARTON. But over time some of these more non-conventional renewable sources kicking in——

Mr. GARMAN. Yes, sir.

Mr. BARTON. [continuing] if we invest in them.

Mr. GARMAN. If we make hydrogen from coal, we want to be careful to also be able to develop the carbon capture and sequestration technology that makes that possible, because we don't want to taint hydrogen as a clean energy carrier with a dirty method of production. We do not want to do that, despite what some I think of the administration's critics have said.

But it is possible, if we are making hydrogen from coal, and we have sequestration technologies that are $15 per ton of carbon emissions avoided, we might be able to get the price of hydrogen down below $1 from coal. And, of course, that is a very big "if," being successful on the sequestration side, and that is a very important part of this equation over the long term.

Mr. BARTON. But if we could do that, that would be a good thing, since we have——

Mr. GARMAN. That would be a——

Mr. BARTON. [continuing] a lot of coal resources in this country.

Mr. GARMAN. Your constituents would be happy about the price.

Mr. BARTON. We all want happy constituents.

Mr. GARMAN. Yes, sir.

Mr. BARTON. That is a non-partisan goal is happy constituents on both sides of the aisle. Talk a little bit about the government role in infrastructure investment. I used to have a natural gas-powered vehicle, and I finally gave up on it, because it was a real pain in the bottom to fuel it.

Mr. GARMAN. That is right.

Mr. BARTON. I had to get the post office to put in a fueling station in Ennis, Texas, because there were no commercial gas—natural gas stations. And then, TXU put in fueling stations in the Dallas Metroplex, but you couldn't go up and use your Visa card. You had to get a special natural gas credit card from TXU, and they didn't really know how much you were using.

You had to estimate each month how much you used, and it was just an accounting nightmare, because I couldn't have a corporate—I couldn't allow a corporation to subsidize the cost of the fuel or I would break the ethics rules. I mean, it was just—so I finally said the heck with it. Plus, I didn't have a trunk in the car because of the tank.

Mr. GARMAN. Right. It is full of the tank, yes.

Mr. BARTON. So is there a Federal Government role in the infrastructure side of the hydrogen issue?

Mr. GARMAN. There is, not only in developing the technologies, but we will see over time what kind of incentives might be necessary for that. We have had a lot of experience through the Energy Policy Act goals related to natural gas vehicles.

Fundamentally and honestly speaking, I think the real issue with natural gas vehicles, and the reason I don't think they are going to catch on is because they don't offer a consumer something markedly different than the car they are driving today.

You purchase a natural gas vehicle, you are going to probably pay a little bit more up front, you are going to have a more difficult time refueling it, as you have experienced, and you are probably going to get a little less money for it when you sell it. And it is going to drive very similarly, almost precisely like your current car.

So what is really in it for you? Why would you, as a consumer, do that? Natural gas vehicles have superb applications in fleets, which is terrific. But this is not the case for personally owned, light-duty vehicles. And the reason I think that hydrogen is different is some of the concepts that some of the automakers are unveiling on hydrogen vehicles.

It is truly something revolutionary and remarkable that gives you a different kind of driving experience and a different kind of opportunity than anything you can have today. And a case in point is the General Motors vehicle that they call the autonomy or the hy-wire. You can think of it as a vehicle on a 6-inch chassis with all of the electromechanical components you need for the vehicle in this chassis with a very low center of gravity, and on top of that vehicle you can put any variety of body styles you want—SUV, roadster, sports car, it doesn't matter.

And not only does that make it easier for the automaker, because instead of having to have a variety of platforms to offer a variety of models, the automaker can just have one or two platforms to offer a variety of different models for different niches of the market.

And you can even have one chassis with two different bodies if that is what you want, depending on what you want you drive on a given day. And that is something——

Mr. BARTON. Have one for the wife, one for you, and one for the teenage son and daughter.

Mr. GARMAN. Or maybe you want to keep the chassis for 20 years and get a new body every 2 or 3 years. This is the concept that GM has unveiled as just one example, and there are others as well.

Mr. BARTON. My time is way over, so I am going to have to cut it off. But we appreciate the answer to that, and we look forward to working with you.

The gentleman from Maryland is recognized.

Mr. WYNN. Thank you, Mr. Chairman.

Mr. Garman, I take it that there will be multiple sources of generation of hydrogen, based on the President's allocation of resources that Mr. John has indicated. Now, there is $5 million in for coal in 2004. Is that restricted to clean coal technology?

Mr. GARMAN. Yes. It would be restricted, really, to gasification technologies, which lend themselves to a good cleanup and——

Mr. WYNN. Clean coal.

Mr. GARMAN. [continuing] sequestration, yes.

Mr. WYNN. Is there any prioritization? Is natural gas No. 1? Followed by coal? Followed by alternatives? Or is it some other order?

Mr. GARMAN. I don't believe there is.

Mr. WYNN. Okay.

Mr. GARMAN. I think it is a question of timing.

Mr. WYNN. Okay.

Mr. GARMAN. The near-term priority is natural gas, just because that is what we will need——

Mr. WYNN. Okay. The government contribution to the sequestration process, is that where we really come in with Federal grants?

Mr. GARMAN. I understand that is a topic of a later hearing in this committee, but sequestration technology is very important if you want to use coal to make hydrogen.

Mr. WYNN. So that is another step that would be required.

Mr. GARMAN. If you want to make hydrogen without emitting carbon dioxide into the atmosphere, that is what you need to do.

Mr. WYNN. Do you have a recommended figure for the government's contribution to that process?

Mr. GARMAN. The FutureGen project, which my colleague in fossil energy who is not here today, is more——

Mr. WYNN. Just a ballpark. I am not trying to pin you down.

Mr. GARMAN. What the President is trying to do is he has announced a billion dollar initiative called FutureGen, and——

Mr. WYNN. Is that all sequestration and recapture?

Mr. GARMAN. That is focused on both electricity generation and hydrogen generation on a net zero emissions basis, meaning——

Mr. WYNN. Is that above the $5 million for coal that is provided in the 2004 budget?

Mr. GARMAN. That is right.

Mr. WYNN. Okay. Do you believe that as part of the phase-one government investment that there ought to be a commitment to a government fleet of hydrogen vehicles when they are not commercially available but when the technology makes them available?

Mr. GARMAN. I think that government, at the appropriate time—and I can't tell you when I think that appropriate time will be—but I think it is very important for government to be a good first customer of this technology.

Mr. WYNN. What would be the size of the vehicle fleet you would envision for the government commitment?

Mr. GARMAN. I can't make that estimation. And if you would like, I might want to take that question for the record and do some thinking about that.

Mr. WYNN. Okay. You make a comment that the administration's plan to accelerate hydrogen and fuel cell development will enable industry to make a commercialization decision by 2015. What does the government have to do in order for the industry to make that decision by 2015?

Mr. GARMAN. Well, I think we have to, again, in a partnership, in a cost-shared basis with industry, we have to achieve all of our technology goals that we have set forth. And we hope to achieve all of these technology goals by 2010.

Mr. WYNN. So if we do that by 2010, are we then in a position for the industry to start making its commercialization goals?

Mr. GARMAN. If we achieve all of the technology goals by 2010, I think that industry would be hard-pressed to say they can't make the car unless there was some kind of problem with the hydrogen infrastructure.

Mr. WYNN. Okay. In the next panel, both the University of Michigan and the University of California testify that current hydrogen fuel cell programs are not adequately utilizing our universities to the fullest extent. They also talk about the loss of young talent from the schools to industry. Is this an area that you believe the government has a role?

Mr. GARMAN. We just put $150 million on the table last week on inviting universities to partner with other partners to help move some of this dollar into research labs, not only in universities but in national labs, the private sector, and elsewhere. We think universities——

Mr. WYNN. So it is not solely universities. They are competing against private labs again. I am speaking specifically of universities.

Mr. GARMAN. Right.

Mr. WYNN. How much for just universities?

Mr. GARMAN. I will have to provide that for the record.

Mr. WYNN. Would you——

Mr. GARMAN. Yes, sir.

Mr. WYNN. [continuing] provide that information?

Mr. GARMAN. But in general, we like to offer research on a competitive basis.

Mr. WYNN. Okay. Finally, looking at your map there, the government's role is infrastructure support. What do you envision us doing in terms of infrastructure support to address the concern the chairman raised about how you fuel up your new hydrogen car?

Mr. GARMAN. Part of that is in the technology validation or demonstration activities for which we just put $150 million on the table. We think that there is a lot of learning that needs to be done, and we have already done a lot of work.

For instance, we have safe hydrogen refueling available today at several locations around the country. We are still working on what is the right kind of vehicle fueling infrastructure interlock that makes sure that no hydrogen escapes when you are refueling the vehicle. We are still making sure that we have a totally safe and convenient refueling experience for a customer when they go to refuel a hydrogen vehicle.

And, of course, we are still working on bringing down the costs of compressors, storage technology, and other things that would be associated with a hydrogen infrastructure. Cost and reliability are some of our major drivers in this R&D work.

Mr. WYNN. All right. Thank you very much.

Mr. GARMAN. Thank you, Congressman.

Mr. SHIMKUS [presiding]. The Chair recognizes the gentlewoman from California. Mary, do you seek time to——

Ms. BONO. No, thank you, Mr. Chairman.

Mr. SHIMKUS. Then, the Chair recognizes the gentleman from Maine, Mr. Allen, for 5 minutes.

Mr. ALLEN. Thank you, Mr. Chairman. I will try to be brief.

Mr. Garman, I think this is a good project. I mean, there are benefits from a hydrogen-based economy and a hydrogen-based vehicle fleet that are obvious—cleaner air, emission from auto—from vehicle emissions is the most obvious. I have a couple of concerns.

No. 1, there is the concern we have already talked about, which is how much emissions, particularly how much in the way of carbon emissions, come from creating the hydrogen itself. And I am also wondering about the arguments you make to—the arguments you make for—not you, but anyone might make for a hydrogen-based economy.

So I have two questions there. One is, can you say whether or not the kind of conversion to a hydrogen-based vehicle, fleet of vehicles that you are anticipating, would that reduce our dependence on fossil fuels? And, two, would it reduce our dependence on foreign sources of fossil fuels? I mean, those are the two questions that remain in my mind.

Thank you.

Mr. GARMAN. If we look back on this first chart, you see that what we portray there is the entire amount of oil demanded by transportation. And if you look at automobiles and light trucks specifically, this is our target. This is the market for which we think fuel cells are most suited. Heavy trucks, rail, shipping, air—these are not a fuel cell market, except in some niche applications.

So you can see the petroleum reduction benefit that would accrue were you to change the entire light-duty fleet over to hydrogen fuel cells.

Mr. ALLEN. Mr. Garman, I missed your comment when this chart went up at the beginning of the hearing. Could you explain that to me?

Mr. GARMAN. Sure.

Mr. ALLEN. How do I see that?

Mr. GARMAN. That chart basically portrays declining domestic production of petroleum against the ever-increasing demand for petroleum in the transportation sector. And that is projected out to 2020. And were I to have a bigger chart, you just see that there is really no end to the growth that is projected.

So what this tells you—if we are fully successful, we believe that by—and I have to caveat this heavily, because when you are talking about predicting the future there is a wrath of uncertainty.

Mr. ALLEN. I am with you on that.

Mr. GARMAN. But we think that it is possible that by 2040 light-duty vehicle oil consumption could be reduced by 11 million barrels per day. And we predict that by 2040 light-duty vehicle carbon emissions are reduced by more than 500 million metric tons of carbon equivalent. So this is the brass ring, Congressman. This is the method.

We have done some other analyses where we try to map the impact of increased CAFE or drilling in the Arctic National Wildlife Refuge. And while we think both of these things are important, they don't change the game. This is the only technology we know of that can change the game and still make available to individual consumers and Americans this freedom of personal mobility that they have come to expect.

Mr. ALLEN. One quick question. The line for domestic production, that is the domestic production for oil?

Mr. GARMAN. Yes, sir.

Mr. ALLEN. And is the assumption in drawing the line that that is the trend that you expect? I mean, that is not a line that is affected by decisions about hybrids or hydrogen vehicles, or anything like that.

Mr. GARMAN. No.

Mr. ALLEN. That is just the line you expect for——

Mr. GARMAN. Domestic production is on a downward trend, and we have a relatively mature petroleum province here in the United States where a lot of the petroleum that is available has been explored.

Mr. ALLEN. Okay. Good. Thank you.

Mr. SHIMKUS. Thank you. And I am going to just follow up with a couple questions. On the chart there, domestic production, does that refer to the crude storage of reserves in the United States? Or does that include imported crude? And does that include refinery? What does that tell me?

Mr. GARMAN. That is just simply domestic crude oil production in million barrels per day.

Mr. SHIMKUS. Domestic, not——

Mr. GARMAN. Domestic.

Mr. SHIMKUS. So you are not addressing imported.

Mr. GARMAN. No, sir.

Mr. SHIMKUS. Okay. And I am glad to see you have got your able assistant Jodi Hansen working. We are know her well, and that is good.

The last question is: the future gen project—you should be receiving a letter—DOE should be receiving a letter from Congressman Costello, my colleague, with an invitation to visit Southern Illinois University at Carbondale to go over all of the stakeholders in our desire to obviously promote, we think, a very suitable location for the DOE to look at.

That has my full support, and I am using this opportunity to formally lobby you in front of millions of Americans that we have a good place for that to be located, and that is in Southern Illinois. So if you would follow up on that.

And with that, having no other individuals here, we would like to thank you for your time, and then we will call the second panel.

Thank you, Mr. Garman.

Mr. GARMAN. Thank you, Mr. Chairman.

Mr. BARTON. The second panel can be seated. We want to welcome our second panel from the private sector. The Chair is going to recognize Congresswoman Bono to make a personal introduction of one of her constituents.

Ms. BONO. Thank you, Mr. Chairman. I am happy to welcome Catherine Rips today. She is from my district, California's 45th Congressional District, and she is a leader in the field of alternative fuel research and development. She is representing SunLine Agency, and she has been with them since 1997. In her current capacity, she is responsible for hydrogen advocacy, public education, and project development.

Welcome to Washington, DC. I hope you enjoyed the commute. I do it every week, so hopefully you will have some sympathy for me now. Glad to have you here.

Thank you, Mr. Chairman. And you very much for inviting her.

Mr. BARTON. Thank you.

The Chair also wants to briefly, on behalf of Congressman Chris Cox, recognize Dr. Scott Samuelsen. Congressman Cox had hoped to be here to introduce you to the panel, but he is Chairman of the Homeland Security Select Committee and he is involved in a hearing with that committee.

But I asked his staff to put together a small introduction, and they gave us a page of single-spaced comments. Professor Scott is from the University of California at Irvine. He directs various research projects on clean and renewable energy sources, including hydrogen refueling research for the South Coast Air Quality Management District and hydrogen-fueled vehicle market research with the University of California Institute for Transportation Studies.

He has just recently directed the introduction of the first commercial hydrogen fuel cell vehicle into the United States. Over the next 6 months, he is going to oversee the installation of two public refueling stations in Orange County. So he has got a distinguished career in the issue before us, and we are very happy on behalf of Congressman Cox to welcome you to the subcommittee.

We also have Mr. Byron McCormick, who is the Executive Director of Fuel Cell Activities for a small company called General Motors. We are glad to have you.

We have introduced Ms. Rips. We have Dr. Francis Preli—is that——

Mr. PRELI. Preli.

Mr. BARTON. Preli. Who is Vice President of Engineering for UTC Fuel Cells. We have Mr. Greg Vesey.

Mr. VESEY. Vesey.

Mr. BARTON. Vesey. See, my staff told me how to pronounce these, and I have already botched two of them. So I apologize. The staff got it right. I can't read their hieroglyphics here. He is President for Technology Ventures for the ChevronTexaco Corporation.

We have introduced Dr. Samuelsen, and we have Dr. Johannes Schwank. Did I get that right? One out of three is not too bad. Dr. Schwank is with the University of Michigan, the Department of Chemical Engineering.

Lady and gentlemen, we are going to recognize each of you, and we are going to start with Mr. McCormick. We are going to ask that you try to summarize your testimony in 5 minutes. And if you go a little bit over, you know, that is acceptable. So welcome to the subcommittee.

STATEMENTS OF J. BYRON McCORMICK, EXECUTIVE DIRECTOR, FUEL CELL ACTIVITIES, GENERAL MOTORS RESEARCH & DEVELOPMENT; CATHERINE RIPS, DIRECTOR OF HYDROGEN PROGRAMS, SUNLINE; FRANCIS R. PRELI, JR., VICE PRESIDENT, ENGINEERING, UTC FUEL CELLS; GREGORY M. VESEY, PRESIDENT, TECHNOLOGY VENTURES, CHEVRON TEXACO CORPORATION; SCOTT SAMUELSEN, UNIVERSITY OF CALIFORNIA AT IRVINE, MECHANICAL, AEROSPACE, AND ENVIRONMENTAL ENGINEERING; AND JOHANNES SCHWANK, DEPARTMENT OF CHEMICAL ENGINEERING, UNIVERSITY OF MICHIGAN

Mr. McCORMICK. Mr. Chairman, members of the committee, thank you for the opportunity to be here to testify on behalf of General Motors. I am Byron McCormick, the Executive Director of General Motors, Fuel Cell Activities. And I guess put simply, I head the team that is developing both our hydrogen and fuel cells, as well as the vehicles that use them.

Fuel cells and hydrogen are the core of GM's advanced propulsion strategy. We are improving fuel economy and emissions of our vehicles by executing a comprehensive, three-phase strategy, including advanced internal combustion engines, new transmissions, as well as hybrid vehicles.

But the ultimate and most important initiative we have is to establish leadership in hydrogen and fuel cells. And so today I would like to tell you why General Motors believes hydrogen and fuel cells are so critically important.

I think as Secretary Garman said, fuel cells running on hydrogen fuels are ultimately the most environmentally friendly vehicles, because their emission is only water. Fuel cell vehicles are on the order of twice as efficiency as the internal combustion engine, have no pollution, have no pollutant emissions, and are quiet.

The fuel cell vehicles enable, very importantly, energy feedstock diversity, which will increase energy independence and introduce competition in energy pricing. And so to some of the questions we heard earlier, once you get that competition and some of the volatility that we think about in the petroleum markets certainly has dissipated, and then hydrogen fuel cells also can substantially reduce greenhouse gas emissions.

Fuel cell vehicles, on a well-to-wheel basis, using current technology demonstrate the potential to greatly reduce the greenhouse emissions, and over time we think we can really drive that down to a very low number.

Fuel cells also enable innovative vehicle designs that show promise of being more compelling, affordable, and, in the end, sustainable than today's vehicles. I think the important point that I want to make around this subject is that for all the technology we talk about, it doesn't do any good if the consumers don't buy it. And so this notion of the compelling vehicle is absolutely critical to this transition we are talking about.

Finally, fuel cells are potentially not only the source of transportation power but electric power, and I want to expand on that a bit in several dimensions. The development of this technology will create more environmentally compatible distributed electric power generation possibilities.

And, in fact, an extension of that is that the automobile could provide electric power for some homes and work sites, particularly during peak times. For example, if only 1 of 25 cars in California today were a fuel cell vehicle, their generating capacity would exceed that of the electric utility grid, because a typical car has maybe 50 to 75 kilowatts of electrical power, where a typical house uses 7 to 10 kilowatts at peak load.

GM's commitment to fuel cells is clear. We have spent more than $1 billion to date, and the number is growing.

The investment in our fuel cell program has yielded outstanding results. In the last 4 years, we have decreased the size and weight of our fuel cell stack for a given power by a factor of 10. With each new generation of technology, we have also greatly reduced the cost and complexity of our stacks, and we are now able to start fuel cells in freezing conditions, down to minus 40 Celsius, in less than a minute, which is, of course, one of those critical parameters if you are going to have cars out there on the road.

We have also created the autonomy fuel cell concept, which Secretary Garman referred to, and a drivable version of that called the hy-wire. These vehicles combine fuel cells and what we call by-wire electronics—that is, sort of aerospace technology—in a revolutionary way that genuinely reinvents the automobile.

These designs could make vehicles both more affordable and more compatible for our customers, because they enable substantially enhance functionality with fewer vehicle components, a longer life chassis, and a smaller number of vehicle architectures. And all of that actually leads to a better business proposition for us in terms of the capital intensity of our business.

As several people have noted, we are also testing fuel cell vehicles in the real world. Over the next few years, we will be fielding several small—and I want to emphasize small—demonstration fleets, because while the technology is immature, I don't think you want to put too many out there.

And, of course, as somebody noted earlier, GM and Shell recently began a joint demonstration program here in Washington, DC to test fuel cell vehicles and the hydrogen fueling technology. This is a 2-year program, which began earlier this month, and it will give government officials like yourselves and your staffs the chance to experience first hand not only driving fuel cell vehicles but, in fact, fueling them.

These milestones represent remarkable progress. In fact, we believe our rate of progress will allow us to market stationary fuel cells mid-decade, and we have already started to do that, and introduce hydrogen fuel cell vehicles by 2010.

Now let us talk about the challenges, and I guess there are three in general—hydrogen storage, cost, and the fuel infrastructure. Relative to hydrogen storage—this is really an important issue—GM has demonstrated both cryogenic liquid and compressed hydrogen storage tanks in our prototype vehicles, and, in fact, here in Washington you will be able to experience both.

While these methods will definitely suffice for early market introduction and early volumes, over the long term we should seek solid storage technology, such as chemical or metal hydrides, which will more efficiently and cost effectively store progressively more hydrogen on board the vehicle.

Relative to cost, inside General Motors are key challenges costs. Our goal is to attain a cost target of $50 per kilowatt for our fuel cell propulsion system That is not just the fuel cell; that is hydrogen in to torque at the wheels by 2010. And this equates to the cost of a conventional internal combustion engine.

As we reduce the cost, you get automotive scale applications. Many attractive business opportunities for stationary fuel cells are, in fact, developed. In fact, we see distributed electric generation as a key stepping stone to the introduction of fuel cell vehicles.

Working with our strategic partner, we have developed several fuel cell generators using the same fuel cell technology we are using in our vehicles. Earlier this month—again, here in Washington, DC—we announced an agreement by which Dow Chemical will purchase 35 megawatts of fuel cell power from General Motors.

Under the 7-year agreement, 500 fuel cell units will convert—and this is one of those cases, where does the hydrogen come from? This is a co-product of their chemical industry, and we will convert that directly into electricity in Freeport, Texas.

Real-time power markets and common interconnection standards, therefore, are really key for these small-scale fuel cell power units to roll out of the lab, and, by extension, help us with the fuel cell vehicles. And I think it should be really emphasized here as we talk about the infrastructure that a hydrogen fuel cell distributed electric generator is a potential hydrogen filling station, since hydrogen, by definition, is available at that location, which means that the distributed electric generation grid is a critical stepping stone to creating the hydrogen infrastructure.

The third challenge we have to overcome is developing and implementing business models for the deployment of the hydrogen infrastructure. We talk about central manufacture and distribution, but I think we should emphasize that hydrogen can as well be generated at local filling stations from gasoline, natural gas, using an appliance-like device called a reformer.

Hydrogen also offers the potential for home refueling using either an electrolyzer or natural gas at home, and this takes advantage of the fact that water, electricity, and natural gas are readily available at our homes and businesses.

Relative to natural gas, there should be sufficient supplies of natural gas to produce hydrogen in the early years of fuel cell introduction. We estimate that if we had 1 million fuel cell cars on the road, and all of the hydrogen of those cars came from reformed natural gas, it would demand above our current usage of natural gas two-tenths of 1 percent.

If you had 10 million fuel cell vehicles, it would increase the current demand by about 2 percent. And I might note that the desulfurization of gasoline that is used in our cars uses a lot of hydrogen generated from natural gas. That is the way you actually get the desulfurization. If you use that, it turns out you could power 10 percent of the fleet just by converting the hydrogen that is used to desulfurize today to hydrogen that you could power vehicles with.

So where is General Motors? We recognize that to make this transition is going to require a three-way partnership involving certainly the auto industry, certainly energy companies, or people who may become energy companies—I don't want to restrict it to just the folks that are there—and government certainly to successfully commercialize hydrogen fuel cell vehicles, and, importantly, stationary applications.

There are a number of areas where the government could have an immediate impact. We would welcome an extension of the national R&D initiative on hydrogen storage, and, again, leverage government labs, universities, and industrial research organizations.

We would like to see an aggressive similar R&D program focused on breakthrough fuel cell materials, but those beyond the 2010/2015 timeframe that we are commercializing. We also believe that Department of Transportation should undeclare hydrogen as a hydrogen material and treat it as a fuel.

And since the Federal and State agencies will have a role in transition to the hydrogen economy, they should begin that process by evaluating the use and impact of hydrogen fuel cell technologies on their operation.

And finally, and perhaps most importantly, the government should take a lead in developing national templates of code standards that will be required for hydrogen fuel cells and, again, importantly, electric distributed generation.

To summarize, we see that fuel cells are the long-term power source. We see hydrogen is the long-term fuel. With continued progress in the technology, we think fuel cell vehicles will be cost competitive by the end of this decade. We think stationary fuel cells will pave the way for fuel cell vehicles. We think that the hydrogen—when we think of the hydrogen infrastructure, we think of appliances, not just pipeline.

We are focusing on small demonstration projects for the next 3 to 5 years. And in the 5- to 10-year timeframe, we see industry cooperating with government on larger scale, rail commercial projects as opposed to demonstrations, that will lead the legacy of an infrastructure.

In closing, hydrogen and fuel cell based transportation is the future. The pace of technical progress is accelerating. The U.S. cannot be left behind or sitting on the sidelines. It is clear that we have intense global competition for leadership in this race to establish and commercial hydrogen and fuel cell technologies, and we think now is the time for the government, U.S. industry, U.S. universities, to create the partnership that will lead the world in the change.

General Motors and our partners are driving to bring first generation fuel cell technology to market as quickly as possible.

I thank you, and I look forward to responding to your questions.

I might also add that a more expansive view of what I have just talked about was published in Scientific American October 2002. And if you would like, we could enter it into the record.

[The prepared statement of J. Byron McCormick follows:]

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

Mr. Chairman and Members of the Committee. Thank you for the opportunity to be here today to testify on behalf of General Motors. I am Byron McCormick, Executive Director of GM's Global Fuel Cell Activities, and I head the team that is developing our hydrogen-powered fuel cell vehicles.

THE PROMISE OF HYDROGEN FUEL CELLS

Fuel cells and hydrogen are core to GM's advanced propulsion strategy. We are committed to improving the fuel economy and emissions performance of our vehicles by executing a comprehensive three-phase technology plan that includes advanced internal combustion engines and new transmissions in the near term, followed by hybrid vehicles . . . but our ultimate vision is to establish leadership in hydrogen fuel cells.

Today, I would like to tell you why General Motors believes hydrogen fuel cell vehicles are so important.

- Fuel cell vehicles running on hydrogen fuel are the ultimate environmentally friendly vehicles because their only emission is water. The fuel cell supplies electricity to an electric motor that powers the wheels. The fuel cell produces electricity by stripping electrons from hydrogen that travels through a membrane to combine with oxygen to form water.
- Fuel cell vehicles are on the order of twice as energy efficient as the internal combustion engine, have no pollutant emissions, and are quiet.
- Fuel cell vehicles enable energy feedstock diversity, which will increase energy independence and introduce competition into energy pricing—potentially bringing down fuel and energy costs in the long term and making prices more stable.
- Hydrogen fuel cells can substantially reduce greenhouse gas emissions. When we look at fuel cell vehicles on a "well-to-wheel" basis, they demonstrate outstanding potential to reduce or eliminate well-to-wheel greenhouse gas emissions and improve overall energy efficiency, even taking into consideration how we make hydrogen today. In the future, we can do even better, producing hydrogen using methods that are renewable and have no adverse environmental impact.
- Fuel cells also enable innovative vehicle designs that show promise of being more compelling, affordable, and sustainable than today's vehicles. Today, there are over six billion people in the world. By the end of this century, that number will approach 10 billion. Most of these people will reside in emerging economies where the demand for personal transportation is expected to escalate rapidly. Since only 12 percent of the world's population currently own automobiles, if we are to fulfill the aspirations of the remaining 88 percent for the personal freedom that the automobile provides, we must find the means to make our vehicles sustainable, more functional, and more affordable.
- Finally, fuel cells are a potential source not only of transportation power, but also of electrical power. The development of this technology will create new, more environmentally compatible distributed electric power-generation possibilities. The automobile could provide electrical power to homes and worksites. Power on today's electrical grid could be supplemented by the generating capacity of cars in every driveway. For example, if only one out of every 25 cars in California today was a fuel cell vehicle, their generating capacity would exceed that of the utility grid. A typical midsize fuel cell vehicle would produce 50 to 75 kilowatts of electrical power, where a typical household may use 7 to 10 kilowatts at peak load.

GENERAL MOTORS' FUEL CELL DEVELOPMENT PROGRAM

Recognizing the potential of fuel cell technology, approximately six years ago General Motor consolidated and accelerated its fuel cell activities. The GM fuel cell team was given an important directive by management: Take the automobile out of the environmental debate. Regardless of whether the environmental debate is focused on air quality, climate, or overall sustainability, GM leadership recognized that global conditions must inspire bold, thoughtful actions. Our commitment to fuel cells is clear in the significance of our investment—we have spent more than a billion dollars to date, and growing.

This investment in our fuel cell program has yielded outstanding results:

- In the last four years, we have decreased the size and weight of our fuel cell stack for a given power by a factor of ten.

- With each new generation of technology, we have also reduced the cost and complexity of our stack.
- We also are now able to start fuel cells from freezing—minus-40° Celsius (minus-40° Fahrenheit)—in substantially less than a minute.
- We have developed a series of hydrogen fuel cell vehicles, which demonstrate how fuel cell propulsion can be optimized for the existing automobile. Our HydroGen1 prototype holds 15 fuel cell vehicle performance records and has been demonstrated around the world. HydroGen3 is our first fuel cell vehicle able to dispense with a buffer battery, needed in previous generations to meet performance peaks. With an improved electric drive and optimized fuel cell system architecture, HydroGen3 has outstanding acceleration and is capable of easily cruising at 100 miles per hour.
- We also have created the AUTOnomy fuel cell concept and a drivable prototype called Hy-wire. These vehicles combine fuel cells with by-wire electronics and other advanced technologies in a revolutionary design that "reinvents" the automobile. These designs could make vehicles both more affordable and more compelling for our customers because they enable substantially enhanced functionality with fewer vehicle components, a longer-life chassis, and a smaller number of vehicle architectures—all of which have the potential to reduce manufacturing costs.
- We also are testing our fuel cell vehicles in the real world. Over the next few years, we will be fielding several small demonstration fleets. GM and Shell Oil recently began a joint demonstration program here in Washington, D.C. to test fuel cell vehicles and hydrogen fueling technology. The two-year program, which began earlier this month, will give government officials—like you and your staffs—the chance to experience firsthand what driving a fuel cell vehicle is like. Next month, in partnership with FedEx, we will begin our first commercial trial of a fuel cell vehicle. This program, which will take place in Japan, will run for one year. Our HydroGen3 vehicle is being used in both demonstration programs.

These milestones represent remarkable progress. In fact, we believe our rate of progress will allow us to market stationary fuel cell units by mid-decade and to introduce hydrogen fuel cell vehicles by 2010. But even as we are encouraged by our progress to date, it is crucial to recognize that the race for fuel cell development is a marathon, not a sprint. No one should overlook that major economic and technical obstacles must be conquered before these vehicles can be brought to market and can become commercially successful.

FUEL CELL COMMERCIALIZATION CHALLENGES

Hydrogen storage, cost, and fuel infrastructure are the major barriers to commercialization.

Hydrogen Storage: With respect to the vehicle, hydrogen storage is the toughest hurdle. GM has demonstrated both cryogenic liquid and compressed hydrogen storage tanks in our prototype vehicles. While these methods will suffice for early market introduction, over the long term, we should seek "solid" storage techniques such as chemical or metal hydrides, which will more efficiently and cost-effectively store significant amounts of hydrogen on board the vehicle.

Cost: The key economic challenge over the coming years is to reduce cost. Our goal is to attain a cost target of $50 per kilowatt for our fuel cell propulsion system (from stored hydrogen to torque at the wheels) by 2010. This equates to the cost of a conventional internal combustion engine. To this end, we have achieved a cost improvement with each new generation of fuel cell stack technology, and we have a good understanding of the additional progress we must make in reducing the cost of each subsystem to achieve total system affordability.

As we reduce cost to get to automobile-scale applications, many attractive business applications for stationary fuel cells are developing. In fact, we see distributed generation as a key steppingstone to the introduction of fuel cell vehicles. Working with our strategic partners, we have developed several fuel cell power generators using the same fuel cell stack technology as we are developing for our fuel cell vehicles. Earlier this month, here in Washington, we announced an agreement by Dow Chemical to purchase 35 megawatts of fuel cell power from GM. This is the largest contract to date in the fuel cell industry. Under the seven-year agreement, 500 GM fuel cell units will convert co-product hydrogen from Dow's chemical manufacturing processes into electricity and heat for its facility in Freeport, Texas. Dow is also considering using fuel cell power at several of its other plants worldwide.

We also recently announced that we will conduct a demonstration of a 75-kilowatt direct-hydrogen unit in both the U.S. and Japan. We expect to be able to market these units in the 2005 timeframe. Early units are intended to provide backup electricity for uninterruptible power supply systems, such as hospitals and high-reliability data communications networks, and to handle peak power demands. Real-time power markets and common interconnection standards for small-scale fuel cell power units could be a key enabler to the early roll out of stationary applications of our fuel cell technology and, by extension, the early rollout of fuel cell vehicles. It should be emphasized that every hydrogen-fuel cell distributed electric generator is a potential vehicle filling station, since the hydrogen is by definition available at that location—which means that distributed electric generation is a critical steppingstone to the hydrogen refueling infrastructure.

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

One of the more exciting aspects of hydrogen is that there are many scenarios for producing and delivering it. Hydrogen could be generated at local filling stations from gasoline or natural gas, using an appliance-like devise called a "reformer." Hydrogen also offers the potential for refueling at home using an electrolyzer or natural gas reformer. This takes advantage of the fact that water, electricity, and natural gas are already available in our homes and businesses.

Initially, hydrogen will likely be produced from many sources. Steam reforming of natural gas will probably be the first source because industry already uses this technique to produce large amounts of hydrogen—nine million tons per year. This process does produce carbon dioxide—about half as much as gasoline on a well-to-wheel basis. The cost of natural gas would presumably go up due to limited supply. However, it is doubtful that hydrogen demand will increase so rapidly as to adversely affect the supply of natural gas. There should be sufficient supplies to produce hydrogen for the early years of fuel cell introduction. We estimate that if we had one million fuel cell cars on the road and all of the hydrogen for those cars came from reformed natural gas, it would increase the current demand for hydrogen by 0.2 percent. If you had ten million fuel cell vehicles, it would increase current demand by 2 percent.

Petroleum companies have said that hydrogen can be generated from natural gas today at approximately the same cost as conventional fuel. A key issue will be implementation of an efficient new hydrogen distribution system. Implementation would include "on site" creation of hydrogen from various feedstocks via electrolysis and reformer technologies. Again, a key ingredient will be nationally uniform codes and standards to ensure rapid implementation.

CALL TO ACTION

GM has always believed that it will take a three-way partnership involving the auto industry, energy companies, and government to successfully commercialize hydrogen fuel cells for vehicles and stationary applications. There are a number of areas where government could have an immediate impact:

We would welcome a major new national R&D initiative on hydrogen storage and production that would leverage the creative capabilities of our government labs, universities, and industrial research facilities.

We would also like to see a similar aggressive R&D program focused on breakthrough fuel cell materials.

We believe the Department of Transportation should "undeclare" hydrogen as a hazardous material and treat it as a fuel.

And since federal and state agencies will have a role in the transition to the hydrogen economy and they should begin that process today by evaluating the use and impact of hydrogen and fuel cell technologies in their operations.

Finally, the government should take the lead on development of a national template for the codes and standards that will be required for hydrogen, fuel cells, and distributed electric generation.

SUMMARY

To summarize GM's position on the emerging hydrogen economy:

1. **We see fuel cells as the long-term power source.** GM's global fuel cell program seeks to create affordable, full-performance, exciting fuel cell vehicles that meet or exceed customer expectations and emit only water vapor from their tailpipes. We believe that customers will want to buy these vehicles.
2. **We see hydrogen as the long-term fuel.**
3. **With continued progress on technology, we think fuel cell vehicles could be cost competitive by the beginning of the next decade.**

4. **We think stationary fuel cells will pave the way for fuel cell vehicles.** By taking our vehicle fuel cell technology to the stationary power market, we are learning how to improve fuel cell reliability and durability, move further down the cost curve, build the required manufacturing and supply base, and accelerate infrastructure development.
5. **When we think of hydrogen infrastructure, we think of appliances not just pipelines.** Traditional infrastructure such as pipelines and centralized plants is not the only means to provide hydrogen for fuel cell vehicles, although it will be part of the solution. If hydrogen is made from natural gas at fueling stations or homes, it will not be necessary to transport hydrogen. We will need cost-effective and efficient reformer appliances. Similarly, if hydrogen is made via electrolysis, we will need practical and affordable electrolyzer appliances. This is an area ripe for entrepreneurial exploration and rapid implementation. For this reason, we are stressing the need for governmental action on nationally uniform standards for distributed electric generation, hydrogen storage, and safety codes.
6. **We are focusing on small demonstration projects for the next 3-5 years,** to gain engineering knowledge that we will apply to technology development still needed for the vehicle and to increase our cycles of learning with respect to infrastructure requirements and the codes and standards that need to be addressed to enable the use of hydrogen as our future automotive fuel. I would just caution that demonstration projects are costly and require many of the same resources we are using to refine fuel cell technology, particularly on the vehicle side. In the next couple of years, the goal should be to have a limited number of small-scale—but integrated—demonstration projects and then expand those projects later in this decade.
7. **In the 5-10 year timeframe, we see industry cooperating with government on larger-scale, real commercial projects that leave a legacy of infrastructure.**

In closing, I believe hydrogen and fuel cell-based transportation are the future. The pace of technical progress is accelerating. The U.S. cannot be left behind or sitting on the sidelines. It is clear that we are in an intense global competition for leadership in this race to establish and commercialize fuel cell technologies. In Japan, the kyogikai (which are companies operating under government auspices) are developing a program for the implementation of fuel cell technology. Now is the time for the U.S. government, U.S. industry, and U.S. universities to create a partnership that can lead the world in the charge to achieve this vision.

General Motors and our partners are driving to bring first-generation fuel cell technology to market as rapidly as possible.

Thank you.

I look forward to responding to your questions.

Mr. BARTON. Thank you, sir. We are going to give you the Ed Markey Award. It took you 11 minutes and 16 seconds. Somebody once said what is good for General Motors is good for the country.

So we are going to give the rest of the panelists the same amount of time if they wish. Hopefully, they will give a little of that back. So we will see if the rest of them can summarize their testimony in less than 11 minutes. And let us start as a goal around 5 minutes. But, again, we want to hear what you folks have to say, so—and General Motors has set the standard.

And if Congressman Markey were here, he would be very proud of you. You have doubled the time that we allotted.

So, Ms. Rips, we welcome you, and we hope that you can summarize your testimony in 5 or 6 minutes. But, again, we want to hear what you have to say.

STATEMENT OF CATHERINE RIPS

Ms. RIPS. Thank you. If I could have 6, I will be happy.

Mr. BARTON. You have 6.

Ms. RIPS. Okay. Well, thank you very much for that. I greatly appreciate the opportunity to appear before you today. The use of hydrogen in transportation applications is a subject near and dear to my heart. It is something that we live and breathe on a daily basis.

I represent SunLine Transit Agency, the only public transit agency in the country to generate hydrogen onsite and use it in both fuel cell and hythane buses. Hythane, in case you are not familiar with the term, is an ultra-clean blend of hydrogen and natural gas that can be used in natural gas engines that are commercial available today.

For the past 3 years, we have tested natural gas reformers, operated electrolyzers off of grid and renewable solar power, demonstrated storage and dispensing systems. We have also actively participated in the California fuel cell partnership, since its inception in 1999.

Ours is a relatively small transit property located in Coachella Valley or the Palm Springs area. You may know it as the "Playground of Presidents" or the "Golf Capital of the World." Those tag lines have a great deal to do with why we became clean air champions.

Eleven years ago, our board of directors—all elected officials—passed a resolution mandating our wholesale conversion to alternate fuels. Their decision was motivated by a commitment to clean air, public health, and a desire to reduce oil imports. Since 1994, we have operated our public transit, paratransit, and regional streetsweeping fleets 100 percent on clean fuels. We currently operate over 150 vehicles on natural gas, hydrogen, and hythane.

We established the Nation's first clean fuels mall, where all of our fuels are available to the public 24 hours a day. We also established the SunLine Beta Test Center for Advanced Energy Technologies, where in partnership with industry, government, and academia, we test and demonstrate prototype vehicles, distributed generation, and infrastructure technologies to help advance their commercialization.

We have well over 25 million miles of experience on alternate fuels, mostly on natural gas. We have created what we consider a highly replicable model where public transit becomes a regional clean air catalyst.

By launching a public-private partnership with Entergy, a builder and operator of natural gas stations, we were able to build seven public-access natural gas stations. Then, having made fuel available in our area, we took the lead in the DOE's Clean Cities Program and helped local fleet operators take advantage of incentives.

As a result, over 1,000 alternate fuel vehicles now use the CNG stations we developed. We have every reason to believe the same model will work with the transition to hydrogen.

Our approach since day one has been to remove barriers. We stress training, public education, and a top-down commitment. Because of our expertise, we have hosted visitors from 30 countries, including foreign energy ministers and Ambassadors and dozens of transit properties worldwide.

And while, fortunately, we have experienced no significant problems of our own, we truly believe most can be avoided through proper training.

We wholeheartedly support the President's commitment to hydrogen. However, we respectfully request your help with a few problematic issues. First, we see the lion's share of emphasis being placed on light-duty vehicles. But based on past experience, we know it is the heavy-duty sector, and transit in particular, that is most successfully adapted to advance natural gas and hybrid technologies.

We believe transit is the key place to begin the transition to hydrogen. That said, we know that it will take multiple generations before a fuel cell engine can withstand the rigors of 19-hour a day transit service. To achieve commercialization, we need committed, long-term funding for the continued development of a limited number of multi-year demonstration projects.

Without top-down commitment to what we call the path of continuous improvement, the United States will lose this important industry to an international market that appears more ready to support it. Japan, Europe, Singapore, Korea, China, and others are currently outspending us by hundreds of millions of dollars.

Second, because fuel cell technology is not ready for immediate commercialization, we urge you to endorse the Clear Act incentives for natural gas vehicles and infrastructure, and to extend those benefits to blends of natural gas and hydrogen. We can't ignore the present in favor of an uncertain future.

We also enthusiastically support incentives for fuel efficiency and the use of other alternate fuels. We believe there are many paths to reduced consumption of oil, and America needs to ambitiously pursue them all. This is not the time to limit options. It is the time to open doors to innovation.

Last, and critical from our standpoint, we urge you to support early adapters of new advanced vehicle technologies, regardless of whether they are natural gas hybrid or hydrogen. Those of us who take the risk and make the investment to purchase cleaner, new technologies, and improve our energy security and our air quality, have a way of being left with the most expensive version of the least-reliable technology. We need ongoing support to upgrade when improvements become available.

So I would like to leave you with these thoughts. To best support the President's plan, we need to build a program under the FTA with committed funding for fuel cell bus development that runs concurrent with the DOE and DOD program that recognizes R&D for light-duty and heavy-duty vehicles and infrastructure.

We need to address and remove barriers to utilizing hydrogen such as clarifying codes and standards, and we need to improve opportunities for public education, technician training, and technology transfer.

Finally, the private sector has invested billions of dollars in hydrogen vehicle and related technologies. At present time, none of those efforts have generated a profit. We feel incentives are needed to motivate consumers to buy the clean vehicles that are already on the market and encourage infrastructure developers to keep building stations.

While we have all the faith in the world that our technology partners will be successful in bringing down costs and improving reliability, we believe government must ensure its sustained support to encourage the private sector to continue investing.

And last, any time you are near Palm Springs please visit us in Thousand Palms. We will be delighted to give you a tour and show you how these exciting technologies work in a real environment.

Thank you.

[The prepared statement of Catherine Rips follows:]

PREPARED STATEMENT OF CATHERINE RIPS, SUNLINE TRANSIT AGENCY

To reduce dependency on imported oil and increase national security, America must reduce demand, increase supply and *develop sustainable alternative.* SunLine Transit Agency, Thousand Palms, CA, is committed to advancing the commercialization of clean fuel and clean energy technologies. A valuable national resource, SunLine is beginning its fourth year of producing hydrogen on site and using it in prototype vehicles, and in its ninth year of operating transit, paratransit and street sweeping fleets powered 100% by alternate fuels.

The agency has the most hydrogen experience of any transit property in the country is actively working with fuel cell manufacturers, bus manufacturers, system integrators, energy providers, the Federal Transit Administration, U.S. Department of Defense, U.S. Department of Energy, State of California, California Fuel Cell Partnerships and others to create and test the next generation of heavy-duty fuel cell engines and vehicles, hydrogen generation, and distributed generation technologies.

In conjunction with its hydrogen test program and ongoing alternate fuels projects, the agency established the SunLine Beta Test Center for Advanced Energy Technologies at its Thousand Palms headquarters. There, hydrogen generated on site from renewable solar power and reformed from natural gas is used to fuel ultra-low and zero-emission vehicles and stationary fuel cells; prototype advanced transportation/clean energy technologies are demonstrated; and compressed natural gas, liquefied natural gas, Hythane® and hydrogen are available to the public 24 hours a day.

It's one of a kind in the world, and as such, has drawn top-level visitors from 30 countries during the past three years. Delegations have included foreign energy ministers, ambassadors, energy department officials, regulators, automakers, global energy providers and a dozen TV news crews from the U.S., Japan, Germany and Italy.

Since 1994, SunLine has logged 25 million clean air miles and displaced more than 5.5 million gallons of imported fossil fuel. The agency has earned 24 local, state and national awards for environmental leadership and efforts to advance clean fuels technology.

Summary of SunLine's Hydrogen Fleet and Infrastructure Technologies

During the past three years, SunLine has demonstrated and/or performed hot weather testing on a variety of prototype vehicles including: two Hythane® buses (with two additional engines now on test stands at Westport); the Ballard (XCELLSiS) P4 ZEbus; the Ballard P5 Citaro fuel cell bus; the ThunderPower LLC hybrid fuel cell bus; the Georgetown University methanol fuel cell bus; SunBug, the country's first street-legal neighborhood fuel cell vehicle; three hydrogen fuel cell powered golf carts; a pickup powered by a hydrogen internal combustion engine (ICE); five California Fuel Cell Partnership vehicles; and a Shelby Cobra race car with a hydrogen ICE.

At the same time, SunLine demonstrated an HbT/Gaz de France natural gas reformer; a Stuart Energy Systems P3 grid-powered electrolyzer; a Teledyne Energy Systems Altus solar-powered electrolyzer; compression and storage systems; hydrogen and Hythane® dispensers at 3,600 psi. The agency is currently expanding its capabilities to add fueling at 5,000 psi, is awaiting delivery of a new Hydradix natural gas reformer utilizing state of the art autothermal recovery technology, and is a partner in a project to generate hydrogen from wind power. Thanks to the support of Congressman Jerry Lewis and Congresswoman Mary Bono, SunLine is likewise under contract by the National Automotive Center to introduce fuel cells to a Class 8 tractor in a phased approach, with the ultimate goal of demonstrating a diesel fuel reformer/fuel cell/hybrid electric drive train. SunLine partnered with UC-Riverside and is now working with Southwest Research Institute in Texas on this important project. The agency is also under contract by South Coast Air Quality Management District (AQMD) to create station templates for multiple hydrogen infrastructure technologies, and to outline considerations for building natural gas stations for future compatibility with hydrogen; and to test insulated Type III tanks to store both compressed gases and associated cyrogenic liquids.

As a result of our experience, we offer the following strategies/suggestions:

Heavy-Duty Sector Launches Transportation Transition

While we wholeheartedly endorse the President's FreedomCar program and Hydrogen Fuel Initiative, we believe the heavy-duty sector is a more likely launch pad for the transition to hydrogen in transportation applications. Though the sector represents just 6% of the vehicles on the road today, heavy-duty vehicles produce 60% of the NO_X and more than 80% of the harmful PM emissions. By starting the transition in the heavy-duty sector, greater gains can be made with fewer vehicles; heavy-duty engines developed for transit applications can then be used in heavy trucks.

Transit Leads Development, Demonstration and Deployment

Public transportation is perfectly positioned to lead the development and testing of advanced fuels and drive trains, development of public access hydrogen infrastructure, training and public education. Transit has historically adopted advanced low emission technologies. Over the last decade, for example, the market share for natural gas transit buses has increased from zero to 25%. Today, over 6,000 natural gas transit buses and over 500 hybrid electric buses have been deployed or are on order. No such parallel exists in the light-duty sector. If however, the rest of the transportation sectors followed transit's lead, according to information provided by CalStart/WestStart, one of nine corsortia created by RSPA, dependence on OPEC oil would be reduced by half.

Transit districts are the ideal proving ground for new fuels as they operate the buses on fixed routes, utilize centralized refueling facilities, have highly trained mechanics, ongoing safety programs, and a subsidized purchasing system. In addition, transit buses have fewer packaging and weight constraints than passenger cars, and as the photo on Page 2 aptly displays, buses serve as mobile billboards to familiarize huge numbers of people with clean fuels, thus paving the way for acceptance of hydrogen-fueled consumer vehicles.

SunLine's tagline is "Today's Model for Tomorrow's World." When the agency converted overnight to a fleet powered 100% by natural gas in 1994, it created a model that can be used by public transit to speed the transition to hydrogen. The agency worked with a private sector partner, ENRG, a Southern California developer of natural gas fueling infrastructure, to build seven public access refueling stations throughout the Coachella Valley. As a result, natural gas fueling is available 24 hours a day, and no fleet operator is more than a 10-12 minute drive from a station.

Having removed the barrier of lack of availability of fuel, SunLine took the lead in the Coachella Valley's Department of Energy Clean Cities program, and together with ENRG, worked to help public and private fleets access available incentive and grant funds. There are now over 1,000 vehicles utilizing natural gas stations in SunLine's service territory.

While we hear repeatedly the dilemma of "the chicken and the egg"—that automakers can't sell cars until stations are built and no private sector business can build infrastructure for which there is no use—this model, using transit to develop public access infrastructure—can help solve the stalemate.

Efforts Coordinated at Federal Level

A multi-year program with guaranteed funding coordinated by DOE, FTA and DOD must be supported from the top down to ensure the speedy commercialization of heavy-duty fuel cell engines, fuel cell buses and infrastructure technologies. Legislation recently introduced by Congresswoman Mary Bono advances this goal by directing the Department of Energy to provide a minimum of $10 million in funding for six years to support the consortia-based Advanced Vehicle Program to accelerate the commercialization of fuel cell bus technology. We strongly support this legislation as well as the National Heavy-Duty Fuel Cell Bus Initiative, which authorizes guaranteed funding at the level of $25 million per year for fuel cell bus development and multi-year demonstration projects under the Reauthorization of TEA 21. We do not advocate creating a new program. Rather, we support modifying the Department of Transportation's existing Advanced Vehicle Program to focus exclusively on the development of fuel cell buses.

Both programs support our belief that field-testing of fuel buses is essential. Both likewise recognize that because of the current state of technology and expense to taxpayers, demonstrations need to be limited to a small number of transit properties that are thoroughly committed to the success of such programs. Rather than deploying large numbers of test buses, these programs support using funds to improve and demonstrate multiple generations of the technology at designated test sites with a goal of reaching commercialization at the end of the six-year period.

Early Adapters Supported

As previously stated, to reach commercialization in the timeliest way, a limited number of early adapters must be supported through the testing of multiple generations of fuel cells and related technologies. However, most funding mechanisms conflict with this approach. Grantors and appropriators understandably seek to "spread funds around." Unfortunately, in this particular situation, that approach does not best serve the country's objectives.

What we see in the field and have experienced ourselves is that those who take the risk and make the investment to purchase cleaner, new technologies that improve our energy security and our air quality are generally left with the most expensive version of the least reliable technology. As, regardless of its benefit to the country, FTA capital and operating funds cannot be used to support research and demonstration of fuel cell technology and infrastructure, early adapters need ongoing support from some other source to upgrade when improvements become available.

ICE's Play an Important Role

In the case of heavy-duty transit applications, to reach commercialization, the cost of a fuel cell bus needs to be reduced from over $3 million per bus to $300,000, and its life expectancy needs to increase from 1-2 years to 12. Clearly, that is not going to happen overnight. Until such time as fuel cell vehicles are commercially viable and available, those alternatives that reduce our dependence on OPEC oil and improve air quality and public health should be aggressively pursued and incentivized. Among them are vehicles with natural gas, blends of hydrogen and natural gas, and hydrogen internal combustion engines.

We hear but don't understand arguments against continued support for natural gas vehicles and infrastructure. Expanding the use of natural gas vehicles is a logical and practical progression toward developing a hydrogen transportation network. NGV deployment requires commercialization of systems for storing, transporting and delivering gaseous vs. liquid vehicle fuel. Broader use of natural gas requires expanded pipeline fuel delivery systems that, when adapted, can supply the hydrogen needed to fuel the first generation of hydrogen-powered consumer vehicles.

In addition, NGV standards serve as a valuable starting point for the development of comparable codes and standards for hydrogen infrastructure and vehicles, including fuel cell vehicles. There is also widespread agreement that natural gas is the fossil fuel from which it is easiest and least expensive to extract hydrogen and will remain so until renewable sources become economical.

There are currently more than 200 natural gas fueling stations in California and several thousand worldwide. As natural gas infrastructure continues to develop, it will be a simple matter to add equipment dispensers for blends of hydrogen and natural gas (such as Hythane®). By co-developing natural gas, blended fuel, and hydrogen infrastructure, customers are given a gaseous fueling option to meet any specific engine and/or duty-cycle requirement.

Natural gas vehicles in the heavy-duty sector are meeting/surpassing the most stringent emissions standards today. Heavy-duty ICEs burning hydrogen and natural gas blends could have an immediate environmental impact while fostering a better understanding of natural gas and hydrogen among commercial users.

SunLine has and continues to work with the natural gas vehicle industry to test engines using fuel with increased hydrogen content by blending compressed natural gas with variable amounts of hydrogen. Based on emissions tests, even blends with relatively small amounts of hydrogen (20% by volume) have shown dramatic reductions in engine emissions.

Vehicles with internal combustion engines burning hydrogen-natural gas blends are practical, achievable and affordable with existing technology. Most important, they create the only conceivable economic justification for building hydrogen infrastructure in advance of the commercial availability of fuel cell vehicles. This infrastructure growth will catalyze much needed development and refinement of the necessary codes and standards for deploying hydrogen vehicles.

Lessons Learned

Since converting to alternate fuels in 1994, and since the Department of Energy and other funders helped SunLine open its hydrogen facilities in 2000, the agency has accomplished a number of goals and learned valuable lessons. Primary among them are:

- Leadership by elected officials is the most important ingredient. Given clear policy directives and support, implementation is achievable. But follow-through is essential. EPAct is a case in point where policy goals were exemplary but federal agencies didn't follow through. EPAct didn't fail. Those who served as watchdogs failed.

- Training is key to success in any alternate fuel program. Before its natural gas buses arrived, SunLine trained every employee on property to be familiar with the properties and benefits of the new fuel. To train its mechanics and operators, the agency partnered with College of the Desert, it's local community college, to create the first training curriculum for alternate fuels technicians. All mechanics and operators have completed the intensive course and continue to attend regular training sessions. SunLine repeated the successful model with hydrogen. The agency contracted the Schatz Energy Research Center at Humboldt State University to teach a workshop on hydrogen to every employee and board member. Working with private sector and education partners, with funding from FTA, SunLine co-produced the first training manual on *Heavy Duty Fuel Cell Engines and Related Technologies.* Posted on the National Renewable Energy Laboratory's (NREL) Alternate Fuels Data Center website, within the first two months of its appearance, the downloadable curriculum logged 132,000 hits—the most ever recorded in that period of time by NREL.
- Public education is a must. To gain buy-in from your community, you must bring the public along. SunLine conducts outreaches, participates in community events, offers weekly public tours of its clean fuels facilities, operates a speaker's bureau, hosts a website with a clean fuels section. The agency also created an Education Collaborative with private sector partners and South Coast Air Quality Management District to maximize the educational value of its hydrogen facilities. Museum-style interpretive signage explains various technologies; collateral brochures further define tour highlights. The interior of the agency's Zweig Education Building, used for industry and community events, is wrapped in an exhibit that invites those viewing it to be part of the national security/clean air solution.
- Partners are essential. SunLine is a small agency with limited funds and human resources. We could not have achieved all we have without many talented and dedicated partners. Nor could we have achieved as much without the steadfast support of our Congresswoman, Mary Bono, who has championed our clean fuels efforts since taking office. Many of our important partners are listed below:

Education Partners

Advanced Transportation Technologies Initiative (ATTI), College of the Desert—Energy Technology Training Center, Department of Environment /Urban Consortium Energy Task Force, Georgetown University, Humboldt State University—Schatz Energy Research Center, National Science Foundation, University of California—Riverside, CE-CERT

Government Partners

California Air Resources Board, California Energy Commission, City of Palm Desert Coachella Valley Association of Governments, Federal Transit Administration, Imperial Irrigation District, Palm Springs International Airport, South Coast Air Quality Management District, U.S. Department of Defense, U.S. Department of Energy

Technology Partners

Air Products, Allison Transmission, American Public Transportation Association, Ballard (formerly XCELLSIS), California Fuel Cell Partnership, California Hydrogen Business Council, California Natural Gas Vehicle Coalition, California Transit Association, Clean Air Now, Coachella Valley Economic Partnership, Cummins Engine Company, DCH Technology, Detroit Diesel, Dynetek, Engelhard Corp., ENRG, Federal Mogul, FIBA Technologies, Fueling Technologies, Gaz de France, HbT, Hydrogen Components, Inc., ISE Research, John Deere, National Hydrogen Association, Natural Gas Vehicle Coalition, Orion Industries, Ltd., Quantum Technologies, QuestAir, Shell Hydrogen, Southern California Gas Co., Southwest Research Institute, Stuart Energy Systems, Teledyne Energy Systems, Thunderpower LLC, TotalFinaElf, TIAX, UOP, UTC Fuel Cells, Wintec.

Challenges to Fuel Cell Commercialization

Among the impediments to commercialization SunLine has identified are:

- Cost
- Reliability of fuel cells
- Availability/affordability of liability insurance
- The lack of uniform/reasonable codes and standards
- The need for comprehensive public education/outreach programs
- The lack of coordinated programs with sustained funding at the federal level

- The lack of consistency by the government. (For example, CAFÉ standards were passed and rescinded; the Clean Cities Program, though very effective, is in danger of having its budget slashed. Manufacturers and consumers are confused by the changes and now wary of committing to any alternate fuel path.)

Prior Questions Posed by Senate Energy Committee Members

Richard Cromwell III, general manager/CEO of SunLine, participated in a hearing held by the Senate Energy and Natural Resources Committee on April 25, 2003. Following the hearing, we were asked to respond to a number of questions that are likely salient. For that reason, we include them here as they were submitted to the Senate committee.

Q. What are the advantages of using natural gas or another hydrogen carrier fuel as the feedstock for hydrogen in the short term? How will this increased demand for natural gas impact natural gas supply and prices?

A. No technology that exists today can compete on a cost basis with reforming hydrogen from natural gas. Proven reforming technology exists, is cost-effective, and when combined with carbon sequestration, begins to be competitive with electrolysis from a greenhouse gas perspective. If we define "short term" as present day—2020 to 2030, there would be no negative impact on natural gas supplies. Rather, as demand increased, it would become economic to increase production. Beyond 2020-2030, it might be necessary to supplement U.S. natural gas supplies with imported liquefied natural gas (LNG).

All that aside, every possible program should be put in place to make renewables cost competitive for hydrogen production. SunLine has demonstrated solar electrolysis since 2000. It works. We're about to demonstrate wind-hydrogen production as well. But until demand is sufficiently high to lower the cost of production, it will never be competitive. Another "chicken and egg" scenario. The solar and wind industries need incentives and large orders to increase production.

Q. Is it more likely that we will have hydrogen fueling stations, or we will see hydrogen generated in our garages from distribute energy resources?

A. Based on what we're hearing today, it is unlikely home electrolysis units would be cost competitive. However, a home reformer may be feasible. If manufacturers solve the technology issues that currently exist and home reformers become available, there could be a mix of home fueling and stations, but the primary method of delivery will likely be fueling stations.

Q. Should the EPAct alternative fuel vehicle mandate program be continued? If so, how should it be fixed? Should we offer credits toward compliance for investments in fueling stations or use of fuel?

A. Yes, the EPAct mandate program should be continued. It could be improved as follows: Include a study provision intended to promote trading of emissions credits between mobile and stationary sources; provide double EPAct credits for fleets acquiring dedicated heavy-duty alternative fueled vehicles; provide credits for companies that make a significant contribution to the development of alternative fuel infrastructure; and require the GSA to allocate the incremental cost of an alternative fuel vehicle over the entire federal fleet. Currently, GSA charges an agency the entire incremental cost of an NGV.

Substitute language, endorsed by our partners in the Natural Gas Vehicle Coalition, follows:

"Sec. 13265. The Secretary shall establish an optional program under which fleets subject to the requirements of sections 13251 or 13257(o) of this subchapter may opt out of the requirements of those sections by making a demonstration to the satisfaction of the Secretary that the fleet or covered person is in good standing with the regulations issued pursuant to sections 13251 or 13257(o) and that the fleet will achieve reductions in the use of petroleum fuels if it is permitted to opt-out of the requirements of these sections. The program established by the Secretary shall by rule:

(a) Establish a measurable annual petroleum reduction requirement for a covered fleet equal to the amount of alternative fuel the fleet would use if at least 60 percent of the annual amount of fuel used in all light duty motor vehicles owned or otherwise controlled by the fleet was alternative fuel.

(b) Allow a fleet that opts into the program to achieve petroleum reduction in any manner it chooses, except that reductions in the size of the fleet shall not be considered in determining the total amount of petroleum reduction by the fleet."

Q. If we are moving to a fuel-cell based transport fleet, should we still be interested in ethanol, biodiesel, natural gas, etc., or should we just use them to make hydrogen?

A. We should *absolutely* still be interested in and provide incentives for purchase of alternative fueled vehicles (AFVs) powered by ethanol, biodiesel, natural gas, and hydrogen-natural gas blends, as well as for hybrid vehicles that dramatically increase fuel efficiency. As, if not more important, we should provide incentives for purchase of alternative fuels at the pump. AFVs can't reduce foreign oil and lower emissions unless they alternate fuels are consumed.

Unlike SunLine, which parked a fleet of diesel buses and went into service overnight with a new fleet powered by natural gas, as a country, we will *never* see a wholesale conversion at any point in time to a new fuel (hydrogen or otherwise). What we've seen repeatedly this past 10 years is that different clean fuels fit different circumstances and what works in one location/situation may not in another. Options should *never* be limited. Our goals (displacing imported petroleum and improving air quality) should be fuel neutral. What should be mandated or regulated is the outcome—not the fuel type.

Q. Aside from new R&D funding, what can/should Congress do to hasten development of hydrogen-fueled vehicles?

A. Revise DOE's timetable from 2020 back to 2010-2015; increase the purchase and use of hydrogen vehicles by federal fleets; pass sustained, guaranteed funding for research, development and demonstration of heavy duty fuel cell transit buses; offer incentives for infrastructure development.

Q. Which policy actions are more important for deployment of advanced technology vehicles—R&D, tax incentives, demonstration projects or regulations?

A. No one action can be singled out. A coherent program is needed that addresses all of the above. Transitioning to a hydrogen economy has been likened to putting a man on the moon. Many in the industry think it will be more difficult! We have to do everything possible as a concerted, coordinated effort to move the technology forward.

Q. Give the focus on hydrogen as the transportation fuel of the future, how much effort should we expend on using other alternative fuels? For example, should we use natural gas directly for transport or convert it to hydrogen first?

A. We will never see a wholesale conversion at any point in time to a new fuel (hydrogen or otherwise). Use of all alternative fuels should be encouraged/rewarded. Every gallon we use (or gas gallon equivalent) reduces our dependency on imported oil, reduces airborne pollutants and reduces greenhouse gases.

Q. Where is the U.S. compared to Europe and Japan in terms of competitiveness for the emerging hydrogen market? Will this new initiative push the U.S. ahead of its competition?

A. While this question was likely directed toward the passenger car market, my answer addresses the heavy-duty transit bus market. There are currently seven fuel cell transit buses on order in the U.S. compared to 30 buses that will be delivered to 9 European cities and Australia through the EU's multi-national CUTE program. Japan, Singapore, and a group of undeveloped nations working with the World Bank and UNDP likewise have programs underway. Despite the fact that transit buses are the most visible vehicles on the road, and that public transit is the ideal launch pad for a fuel cell program (because of centralized fueling, bus size/shape, and having trained mechanics and operators), the U.S. has no committed, sustained funding for the ongoing development/refinement of heavy-duty fuel cell buses. Through our experience, we've learned it will take several generations of engines before a fuel cell can withstand the rigors of the public transit environment. Without a multiyear commitment to technology development and demonstration, the U.S. will absolutely not be competitive with Europe or Japan in this market.

Q. What kind of coordination is occurring between the Department of Transportation and Department of Energy regarding the demonstration fleet vehicles including transit buses?

A. From our standpoint, in the past, there has been little coordination between the two departments. We recently attended an industry meeting where a DOT rep stated his department's role began at the point where new technologies were ready for deployment. DOE, however, does not fund heavy-duty transit bus R&D—which leaves transit operators in a crack in the system. We need a coordinated program for research, development and demonstration of multiple generations of fuel cell buses and corresponding funding for continuing hydrogen infrastructure upgrades in order to have a success. We have the same problems with early generations of hydrogen generating, storage and dispensing technologies as we do with early generations of fuel cell bus engines. The early generations can't withstand the daily rigors of the transit environment over a multi-year period. We need continued funding for early adapters to upgrade to each next generation to improve reliability, efficiency, and cost.

Q. What makes us think the Hydrogen Fuel Initiative will be any more successful than programs in the past to deploy alternate fuels and displace petroleum?

A. The U.S. government has the opportunity to correct all prior mistakes in regard to transitioning to a new, cleaner fuel. For the first time, efforts could truly be coordinated between the Departments of Defense, Energy, and Transportation so each has a pre-planned role in reaching the same end point. In addition, the government can look to successful models between government, industry, energy providers, OEMs, and transit agencies such as the California Fuel Cell Partnership to learn how to leverage the efforts of multiple stakeholders. One final thought is that the RFP process and the earmark process don't particularly support the advancement and deployment of emerging technologies. The Consortia-based Advanced Vehicle Program was far more successful in bringing new technologies to the marketplace than other government programs.

Earmarks tend to fragment funds and no coordination between projects is required. RFPs are very specific and exclude many very viable and necessary projects (and in some cases, manufacturers) because of technicalities that often contribute little to the outcome. A better system is to establish a pool for projects of a certain type and rank them on what they add to the country's objectives, which is how the Consortia-based program brought hybrid technologies to the marketplace. While every consideration should of course be given to U.S. technologies, it is self-defeating to exclude or penalize foreign automakers, bus makers, and/or manufacturers whose products perform better than similar American products. The goals are to reduce foreign oil imports and improve air quality—not subsidize American industry.

Legislators at SunLine

Among our many recent visitors were Senator Barbara Boxer, who presented SunLine with a Conservation Champion Award in February 2002, Congresswoman Mary Bono, who attended the October 2002 launch of the ThunderPower hybrid fuel cell bus into revenue service (and actually drove the bus!), and Senator Byron Dorgan, who attended a hydrogen briefing conducted by CalStart/WestStart and SunLine March 2003.

We extend the same invitation to all House Energy and Commerce Committee members to visit "Today's Model for Tomorrow's World"—SunLine Clean Fuels Mall.

Mr. BARTON. Thank you.

Mr. Preli, you are recognized for 5 minutes plus.

STATEMENT OF FRANCIS R. PRELI, JR.

Mr. PRELI. Thank you, and good morning. My name is Frank Preli. I am Vice President of Engineering for UTC Fuel Cells, a business of UTC Power, which is a unit of United Technologies Corporation.

I appreciate the opportunity to participate in today's hearing. UTC Fuel Cells is one of the largest and most experienced fuel cell companies in the U.S. and the world. We are the only company addressing space, stationary, and transportation markets. UTC Fuel Cells employs a total of 850 individuals with a team of 350 engineers and scientists focused solely on fuel cell research and technology development. Over the years, our employees have amassed more than 550 U.S. patents relating to fuel cell technology.

UTC Fuel Cells produced its first fuel cell in 1961 for space application, and then we have supplied all of the fuel cells for the U.S. manned space missions. UTC Fuel Cells has also led the way with terrestrial fuel cell applications. We have sold 255 stationary 200-kilowatt size units, known as the PC25, to customers in 25 States, 19 countries, 5 continents. This also includes the powerplant that Congressman Wynn referred to, the police station in New York City.

Our installed base of PC25's has generated over 6 million hours of clean energy. We are also a leader in the development of fuel cell systems for the transportation market. We count Nissan, Hyundai, and BMW among our transportation fuel cell partners. In addition, California's only hydrogen fuel cell transit bus and revenue service, operated by SunLine Transit, is powered by one of our powerplants.

Great progress has been made in fuel cell technology. For example, in the past 5 years, the life of the PEM-type fuel cell stacks has been extended from 100 hours to 1,000 hours, and recent laboratory testing has demonstrated lives of 10,000 hours. Costs have also come down dramatically, albeit from a very lofty starting point of $600,000 per kilowatt for space applications to $4,500 per kilowatt for our current stationary products introduced in 1992.

Our next generation stationary product is targeted at an initial cost of around $2,000 per kilowatt, and we have also achieved 50 percent reductions in size since 1997, and the weight has decreased by approximately the same amount. But we still have a very long way to go.

The automotive application is the most challenging based on cost, durability, and performance requirements. The internal combustion has a 100-year head start and benefits from the huge volumes produced today. Therefore, it will take longer for fuel cells to successfully compete in this market, but the auto market also offers the largest payoff in terms of environmental benefits and our ability to reduce the Nation's dependence on foreign oil.

We believe fuel cells will be deployed first in stationary devices, and then fleet vehicles such as transit buses, and only later in the personal auto market. Transit buses are a strategic enabler on the path to autos powered by fuel cells. Hydrogen fueling stations can be made available, given the relatively small number of inner city bus stations, and the powerplant size and weight requirements are less demanding than those associated with automobiles.

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

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

Our recipe for successful fuel cell commercialization is included in my written statement, but the top ingredients here are: 1) development of a comprehensive long-term national strategy with sustained national commitment and leadership; 2) robust investment by the private and public sector focused on research, development, and demonstration programs for both fuel cells and hydrogen infrastructure, with an emphasis on renewable sources of hydrogen; 3) financial incentives and government purchases; 4) elimination of regulatory barriers; and 5) harmonized codes and standards that permit global involvement with open access to markets.

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

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

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

Thank you.

[The prepared statement of Francis R. Preli, Jr. follows:]

PREPARED STATEMENT OF FRANCIS R. PRELI, JR., VICE PRESIDENT ENGINEERING, UTC FUEL CELLS

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

UTC Fuel Cells is one of the largest and most experienced fuel cell companies in the US and the world. We're the only company addressing the space, stationary and transportation markets. UTC Fuel Cells employs a total of 850 individuals and I lead a team of 350 engineers and scientists focused solely on fuel cell research and technology development. Over the years our employees have amassed an impressive list of more than 550 US patents related to fuel cell technology.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Thank you Mr. Chairman for the opportunity to testify.

Mr. BARTON. Thank you, sir.

Now we want to hear from Mr. Vesey.

STATEMENT OF GREGORY M. VESEY

Mr. VESEY. Thank you, Chairman Barton, Congressman Wynn, and members of the subcommittee. ChevronTexaco is pleased to have the opportunity to testify before the Energy and Commerce Subcommittee on Energy and Air Quality.

My name is Greg Vesey, and, as President of ChevronTexaco's Technology Ventures, I oversee many facets of our company's advanced energy and technology development and commercialization, including hydrogen generation and hydrogen infrastructure, and can share our experience as well as our views regarding the critical steps required in the development of this technology.

Just by way of background, ChevronTexaco is an integrated global energy company that produces oil, natural gas, transportation fuels, and other energy products. We operate——

Mr. BARTON. We have heard of ChevronTexaco.

Mr. VESEY. We operate in 180 countries and employ more than 53,000 people worldwide. 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.

With regards to fuel cell technology, 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, and there are transportation demonstrations underway. We, in fact, have two stationary fuel cells, one powering a data center in our California office and one powering laboratories in Houston, Texas.

To meet the challenges involved with this new technology, we are involved in partnerships, participating in government and private workshops, and privately fund basic and applied research for hydrogen fuels, storage, and refueling sites. These efforts were underway prior to President Bush's announcement of the hydrogen initiative in this year's State of the Union address, and, subsequently, DOE's solicitation on infrastructure.

The administration's actions provide an impetus for the private sector to focus more attention on the development of this technology. We view new DOE programs as an excellent opportunity to work in partnership with auto companies and the U.S. Government, especially with regard to fuel production and distribution infrastructure.

Developing a hydrogen infrastructure requires the cooperative efforts of government, auto manufacturers, major energy companies, and others. Hydrogen is a fuel, not a natural resource. 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 fuel processing business.

The current level of discretionary capital spending on the refining business segment by integrated oil companies has been close to zero, and investments are being minimized. Integrated energy companies have generally been reducing their exposure to this business because of our inability to achieve an adequate return on capital.

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 for this risk.

The introduction of fuel cell cars must be coordinated with the introduction of infrastructure. We know that the infrastructure must be in place before customers buy these cars. We also know that this will require significant investment, and to be successful the auto companies and energy companies must work together to co-develop solutions and support government in private-public partnerships.

Hydrogen must be available when and where it will be needed. We understand that customers must be confident that hydrogen be available before they will buy cars that are powered by hydrogen. It is a significant task to develop technology, to produce the hydrogen at a reasonable cost, to make it available on a broad geographic area, to store it at the sales point, to fuel the cars. And, in addition, the technology must be employed in a safe manner to achieve total consumer confidence, much as we have discussed today.

There are 9 million tons per year of hydrogen produced and used in the United States. This is equivalent to only 1 percent of the crude oil produced in America. 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 if it is to be used for transportation.

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. 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.

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 may be achievable once the demand for hydrogen is substantial. But as of yet, this has not been demonstrated. The ability to economically supply hydrogen to the market while the demand is low is difficult. One opportunity in this area would be for the 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.

A few public policy recommendations—we believe that there are several areas that are critical to the development of this technology and recommend the following. Support the technology development and validation for hydrogen infrastructure. We see the DOE-sponsored controlled hydrogen fleet and infrastructure demonstration and validation project as a positive step that will create opportunities to move the technology forward.

Public education. It is important that the public understand the market drivers, environmental benefits, costs, and challenges associated with each stage of transition. We must leverage private industry stakeholders. We believe that this will help make the technology commercial, and also focus government priorities on areas where there is most need. The only way to accelerate efforts toward commercialization of this market is for the private industry and government to share the development costs.

And we must monitor market signals. Often we see that factors can change the need for a particular technology, either increasing or decreasing demand. To embark on a long-term major government initiative without doing mid-course reviews would be a mistake. Periodic reviews will be necessary to assess progress and steer or change policy as needed and implement appropriate mid-course corrections.

Thank you for the opportunity to testify. I look forward to questions.

[The prepared statement of Gregory M. Vesey follows:]

PREPARED STATEMENT OF GREGORY M. VESEY, PRESIDENT, TECHNOLOGY VENTURES, CHEVRONTEXACO

Chairman Barton, Ranking Member Boucher, and Members of the Subcommittee: ChevronTexaco is pleased to have the opportunity to testify before the Energy and Commerce Subcommittee on Energy and Air Quality on DOE's hydrogen programs and the future of advanced energy technologies.

As ChevronTexaco's President of Technology Ventures, I oversee many facets of our company's new energy technology development and commercialization, including hydrogen generation and hydrogen infrastructure, and can share our experience as well as our views regarding the critical steps required in the development of this technology.

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 53, 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 ChevronTexaco's Worldwide Power and Gasification business unit is a world leader in gasification technology which is a reliable, efficient, and clean technology that converts hydrocarbons, such as coal, for the production of power, fuels, chemicals and industrial gases, such as hydrogen. Commercial examples of the use of our technology include Tampa Electric Power Company's Polk facility that produces electricity and Eastman Chemical Company's Kingsport, Tennessee facility that produces chemicals.

With regards to fuel cell technology, 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 and there are transportation demonstrations underway.

ChevronTexaco has installed two stationary fuel cells at our facilities in San Ramon, California and Houston, Texas. These fuel cells convert hydrogen from natural gas into electricity, clean water and usable heat, and provide secure digital-grade power to select information technology systems and laboratories. We undertook these projects 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. We are working on hydrogen infrastructure development issues, including production, storage, and distribution.

CHEVRONTEXACO'S RESEARCH AND DEVELOPMENT INITIATIVES

We continue to support development of hydrogen generation and hydrogen storage systems. We are active in research and development to create safe methods for storing and delivering hydrogen. New opportunities to develop the technology may be presented through demonstrations, including the DOE's recently announced "Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project." To meet the 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, storage, and refueling sites. These efforts were underway prior to President Bush's announcement of the Hydrogen Initiative in this year's State of the Union address and subsequently, DOE's solicitation on infrastructure. The Administration's actions provide an impetus for the private sector to focus more attention on the development of this technology. We view new DOE programs as an excellent opportunity to work in partnership with the auto companies, States, the U.S. government and other critical parties, especially with regard to fuel production and distribution infrastructure. Developing a hydrogen infrastructure requires the cooperative efforts of the government, auto manufacturers, major energy companies, and others.

An example of the type of activity that we are involved in includes:

California Fuel Cell Partnership: We continue to work with auto companies, other energy partners and government agencies, to provide hydrogen to operate a project facility that safely delivers high-pressure hydrogen to demonstration vehicles.

In addition, as part of this effort ChevronTexaco engages and supports important R&D initiatives including:

Hydrogen Production: 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. This includes understanding the total environmental consequences and costs of making hydrogen from many different sources. Though many fuel cell systems include reformers that convert natural gas or other fuels to hydrogen at the site, cost effective hydrogen production and distribution technologies will enable a wider range of fuel-cell systems to operate. We are also looking at electrolysis to produce hydrogen from water, however as we focus on the transition to a hydrogen based market it is clear that making hydrogen from readily available hydrocarbon fuels is currently far more cost competitive with today's fuels. We have developed relationships with leading fuel-cell developers, utilities and technology companies in an effort to introduce competitive fuel-cell systems into the market. We have hydrogen generators in long term testing that will convert a hydrocarbon feedstock, such as natural gas or liquid hydrocarbons, into hydrogen.

Delivery of Hydrogen: One other challenge is how hydrogen would be distributed in a decentralized manner. We are working to design a delivery infrastructure that is economic and safe. We are developing infrastructure systems to incorporate and integrate a range of new technologies including hydrogen extraction from natural gas, safe-site storage technologies, and advanced hydrogen detection and control systems to ensure safe handling and use. This is an array of technical challenges that will require involvement of many industry technology providers as well as public and government agencies.

Hydrogen Storage: Hydrogen storage is a critical part of the infrastructure development. Distribution of fuels for commercial use must provide for hydrogen storage. We are currently engaged in the R&D and commercialization of new hydrogen storage technology through partnerships and internal efforts. Our objective is to provide safe reliable products capable of meeting a wide range of applications including small portable, automotive, and bulk storage applications.

COMMERCIAL AND INFRASTRUCTURE CHALLENGES

We have operated in the refining and marketing business segment for over 100 years. The financial investment has been very large. The current level of discretionary capital spending on the refining business segment by integrated oil companies has been close to zero and investments are being minimized. Integrated energy companies have generally been reducing their exposure to this business because of our inability to achieve an adequate 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 and that to be successful the auto companies and energy companies must work together to co-develop solutions with support of government in private/public partnerships.

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. make it available 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. This is equivalent to only 1% of the crude oil produced in America. 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 if it is to be used for transportation.

Storing hydrogen in the car, at the refueling station and throughout the delivery infrastructure is a sizable challenge that is unmet thus far. 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. We are working to develop this technology, but there is still more work to be done before a standard is embraced.

Eventually the hydrogen market may be big enough that we can make hydrogen in large centralized plants, similar to refineries today. But then the hydrogen still needs to be distributed across the country. 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 overcome.

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 be strengthened to ensure safe maintenance facilities. Through research and demonstration of hydrogen generation and storage technology we will be able to gain the necessary safety knowledge which will lead to data driven codes and standards that do not currently exist.

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 may be achievable once the demand for hydrogen is substantial, but as of yet this has not been demonstrated. The ability to economically supply hydrogen to the market while the demand is low is difficult.

Coordination between the auto companies and energy companies for decisions on optimal geographic demonstration fleets of fuel-cell cars and buses will 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 this technology. We recommend the following:

1. *Support the Technology Development and Validation For Hydrogen Infrastructure:* We see DOE's sponsored "Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project" as a positive step that will create opportunities to move the technology forward. It is essential that DOE integrate the infrastructure issues simultaneously with fuel cell vehicle development. Major energy companies that already support this nation's fuel infrastructure have a key role to play in the development of hydrogen based energy. ChevronTexaco is committed to helping the U.S. move towards safe and cost competitive solutions. This should be a high priority in terms of DOE and other government R&D support.
2. *Public Education:* 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. As the hydrogen market evolves over the next few decades, technology breakthroughs will change the way hydrogen is made and supplied to the consumer. It is important that the public understand the market drivers, environmental benefits, costs and challenges associated with each stage of the transition.
3. *Leverage 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. ChevronTexaco has already invested in R&D efforts in the areas of hydrogen generation and storage, however the private sector alone can not provide the resources and capital necessary in a technology that may not see any sort of return for decades. The only way to accelerate efforts towards commercialization of this market is for private industry and government to share the development costs.

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 and public opinion. To embark on a long-term major government initiative without doing mid-course reviews would be a mistake. Periodic reviews will be necessary to assess progress and steer or change policy as needed and implement appropriate mid-course corrections.

I should note that this year's energy bill, H.R. 6, passed by this Committee and the House does include several provisions to address infrastructure issues with this energy 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. BARTON. Thank you, sir.

We now want to hear from Dr. Samuelsen.

STATEMENT OF SCOTT SAMUELSEN

Mr. SAMUELSEN. Mr. Chairman, and members of the committee, thank you for the opportunity to provide testimony today on the hydrogen energy economy. I direct the National Fuel Cell Research Center and serve as a Professor of Mechanical, Aerospace, and Environmental Engineering, at the University of California at Irvine.

The National Fuel Cell Research Center is deeply engaged in the hydrogen infrastructure and fuel cell vehicle. Last December, for example, the Center deployed the first commercial hydrogen-fueled fuel cell vehicle into the marketplace and commissioned a hydrogen fueling station. In the next 6 months, working with the South Coast Air Quality Management District, the Center will deploy in two cities in Southern California additional hydrogen fueling infrastructure.

The frenzy generated by the President's State of the Union address has dramatically accelerated the otherwise controlled and competitive emergence of the hydrogen future. While exciting, this acceleration demands of Congress leadership, I believe, in order to assure a safe, sensible, and successful evolution of the new paradigm.

If you will allow, let me identify 5 examples of congressional leadership opportunity. The first is congressional leadership to assure university research programs that both advance the technologies and basic understanding needed for both hydrogen and fuel cells, but also train undergraduate and graduate students to meet the demands of the emerging industries, some of whom you are hearing from today.

A second area of leadership is needed to prioritize the renewable technologies that will be needed for large volume hydrogen generation. I commend the Office of Energy Efficiency and Renewables, and the leadership of David Garman as we witnessed this morning, for providing the early planning and initial studies and research demonstrations in this area.

Third, recognizing that renewable energy is not sufficient, the congressional leadership needs to facilitate a 20-year roadmap for the development and deployment of fossil fuel-based hydrogen generation technologies that are both energy efficient and environmentally responsible.

The President Future Gen Program is a hallmark step in this roadmap, undoubtedly. Also, the Vision 21 Program that has been successfully initiated by the Department of Energy.

The fourth example is especially profound and may catch you a bit off guard. It is the assurance of the development and deployment of stationary hybrid fuel cell gas turbine combinations. This hybrid—stationary hybrid now—is a synergism that is showing a performance not before seen in engineering of ultra high conversion efficiencies. Fueled electrical conversion efficiencies, for example, of over 75 percent on natural gas.

The leadership of the Department of Energy, Office of Fossil Energy, under the direction of Assistant Secretary Michael Smith, for the development and deployment of such systems will undoubtedly change the manner by which electricity is generated in the future and how hydrogen is generated throughout the world.

Fifth, congressional leadership is needed to provide a path to national standardized codes and standards. We have outstanding codes and standards for industrial use of hydrogen, such as generation and distribution, but not for the public use, such as dispensing and utilization.

The industry and technical societies have done a remarkable job in developing the industrial standards, but this frenzy and acceleration of the hydrogen future creates a responsibility, I believe, for congressional leadership to assure a coordinated evolution of national-based standards that is also integrated into the international community, which is also, of course, not only within the market base but developing standards as we speak.

In conclusion, I thank the committee for the opportunity to comment. The President's leadership has opened a window of opportunity for the hydrogen initiative as outlined in the 2004 budget. But the time to act is limited, and the opportunity for congressional leadership will rapidly close.

I look forward to the questions. Thank you for this opportunity.

[The prepared statement of Scott Samuelsen follows:]

PREPARED STATEMENT OF SCOTT SAMUELSEN, DIRECTOR, NATIONAL FUEL CELL CENTER, UNIVERSITY OF CALIFORNIA

Mr. Chairman and Members of the Committee, thank you for the opportunity to provide testimony on hydrogen, hydrogen-fueled combustion and fuel cell vehicles, and regulatory encouragement for incorporating hydrogen fuel into the consumer-based energy economy. I direct the National Fuel Cell Research Center at the University of California, Irvine, and serve as a Professor of Mechanical, Aerospace, and Environmental Engineering.

The National Fuel Cell Research Center was established by the U.S. Department of Energy and the California Energy Commission in 1998, along with a strategic alliance of industry, to accelerate the growth of fuel cell deployment in the nation and around the world. The principal focus of the Center is the development and deployment of stationary fuel cells systems for home, commercial, and industrial power, and for the fueling infrastructure in support of hydrogen powered vehicles. The stationary fuel cell represents a major role in the hydrogen fuel economy of the future.

To investigate the future, the National Fuel Cell Research Center last December deployed the first commercial hydrogen-fueled fuel cell vehicle into the United States, and commissioned a hydrogen refueling station. Over the next six months, the Center will deploy two addition hydrogen refueling stations in Orange County. The Center conducts the anchor research for the U.S. Department of Energy for the design of stationary fuel cell systems in order to provide energy efficient and environmentally responsible co-production of electricity and hydrogen as a vehicle fuel.

Until a few months ago, the hydrogen future was emerging at a controlled pace with international competitive forces creating both hydrogen-fueled vehicles, and a hydrogen fueling infrastructure. Both are remarkable in their own right as they represent dramatic paradigm shifts for the public: the power plant under the hood on the one hand, and the fuel to power the vehicular population on the other. We are witnessing and experiencing both in parallel.

The gasoline engine has evolved over ninety years to become a reliable, safe, and inexpensive power plant. The gasoline fueling refining and distribution infrastructure has also experienced nearly a century of development to where we today park a vehicle with 20 gallons of liquid fuel in our home garage, often in the presence of natural gas flames that heat water, furnaces, and clothes dryers. We are in the 1920's of the hydrogen fueling infrastructure and fuel cell engine.

The frenzy generated since the State of the Union address has dramatically accelerated the otherwise controlled and competitive emergence of the hydrogen future. While exciting, this acceleration demands a parallel commitment on the part of Congress to provide key leadership and thereby assure a successful, sensible, and safe evolution of these two new paradigms. Allow me to identify five examples of Congressional Leadership Opportunities:

1. Assure a robust and active university research program that both advances the state-of-the-art in fuel cell research and trains the undergraduate and graduate students necessary to the meet the demands of a growing hydrogen and fuel cell industry.
2. Prioritize the evolution of environmentally sensitive and efficient renewable technologies for large scale hydrogen generation.
3. Recognizing that renewable energy will not be sufficient, facilitate a twenty-year technology development and deployment roadmap for energy efficient and environmentally responsible fossil fuel based technologies for hydrogen production.
4. Assure U.S. leadership in the development and deployment of stationary fuel cell/gas turbine hybrid technology that can co-produce electricity and hydrogen at efficiencies exceeding 70 percent, operating on either natural gas or coal.
5. Establish a path to establish national standardized codes and standards for the public utilization of hydrogen.

(1) University Programs.

The National Fuel Cell Research Center has over twenty graduate students, a staff of twelve, and over fifteen faculty. Through its outreach, over one hundred faculty from around the country participate in the "Universities for Fuel Cells" program sponsored by the U.S. Department of Energy, and the U.S. Department of Defense.The fuel cell was invented in 1839, over one hundred and fifty years ago. The first significant use of fuel cell technology was lead by NASA in the 1960's to power space vehicles. Similar to a car battery, fuel cells are fed a continuous flow of hydrogen fuel and oxygen. As a result, they produce a continuous and efficient flow of electricity with virtually no noise and near zero emission of criteria pollutants.

Due to the investment of Congress and industry in fuel cell technology, we are now witnessing the emergence of commercial stationary fuel cells to power homes, commercial buildings, and industry, and the introduction of commercially designed automobiles. We also see the emergence of fuel cells for laptops and bio fuel cells for implantation in the body. The future is, indeed, remarkable and exciting.

The irony is that, while the fuel cell is emerging to become pervasive throughout society over the next two decades, little attention is given to the fuel cell in today's engineering curriculum, and in today's university research. It is tantamount to the emergence of the transistor in the early 1960's. As a result, our graduate students are peeled out of our program by industry before they can conclude their theses and dissertations.

The "Universities for Fuel Cells" program is designed to bring together key researchers from Universities and National Laboratories in order to focus on critical technology areas that are in need of research and development in order to hasten the advancement of fuel cells. The specific focus areas are: (1) materials, (2) systems and controls, (3) power electronics, (4) fuel processing, (5) manufacturing, and (6) simulation. Among its activities, Universities for Fuel Cells hosts workshops to prioritize needed R&D topics for the U.S. DOE, NSF and other state and federal agencies, and to establish collaborative R&D efforts between universities, national labs, industry and agencies. A long-term goal of this effort is to strengthen the university research community so that it may play a role as a full partner with industry and provide attractive career options for our most talented graduate students.

If the national effort to capitalize on the full potential of hydrogen economy is to be successful, a leadership opportunity for Congress is to assure that federal mandates incorporate university contributions. University research not only brings fundamental research advances in engineering, the physical and biological sciences, social and business sciences in supporting the fuel cell and hydrogen future, but also assures that an educated workforce is developed to fill the requirements of industry and assure a strong U.S. presence in national and international fuel cell and hydrogen markets. The current solicitations in support of the hydrogen future do not include substantial university research opportunities. An example and model of a successful engagement of universities in support of a national mission is the recent Department of Energy Advanced Turbine Systems Program. [*Congressional Leadership Opportunity #1*]

(2) Hydrogen Production From Renewables

The hydrogen future portends an opportunity use a fuel that produces only water as a by-product.

This is the public perception by many and reflects a vision conveyed by the President in the 2003 State of the Union.

In reality, water is not the only by-product. For fuel cells (either mobile or stationary) directly fueled by hydrogen, this statement is almost true. In addition to water, a small amount of nitric oxide (a criteria pollutant associated with the formation of photochemical oxidant in urban air sheds) is emitted. Emissions may also include degradation products of the fuel cell stack.

For hydrogen used in combustion engines, the nitric oxide emission will be an order of magnitude higher and comparable to the best engines operating today on conventional natural gas and liquid fuels.

In addition to these by-products that some might argue are minor, there is no argument that major pollutant and greenhouse gas by-products can be emitted in the generation of hydrogen.

While abundant, hydrogen is not available for use without a process to extract and transport the hydrogen from the point of generation to the point of use. If not addressed by Congress, the hydrogen generation to meet future demands will dramatically reduce U.S. energy efficiency, increase fuel dependence, and dramatically increase U.S. environmental impacts. No one of these outcomes is desirable. Congress has the opportunity to assure that a more desirable route emerges.

For example, the most energy and environmentally benign generation of hydrogen is the electrolysis of water using electricity from renewable sources such as wind, sun, and water, captured by wind turbines, photovoltaic cells, and hydroelectric turbines. For these technologies, air pollutant emissions will be associated only with the transport of the hydrogen to the point of use. For transport by diesel truck, emissions will include NO, carbon monoxide (CO), hydrocarbons (HC), and particulate (PM). For transport by pipeline, emissions will be associated with the electricity needed to power compression of the hydrogen to elevated pressures.

I commend the Office of Energy Efficiency and Renewables and the direction of Assistant Secretary David Garman on the planning and early initiatives in this area. Technology and policy to incentivize and sustain a major deployment of renewable energy for the production of hydrogen, and the use of pipelines to transport the hydrogen to the point of use should serve as a major focus for Congressional leadership to assure an environmentally responsible hydrogen future. [*Congressional Leadership Opportunity #2*]

(3) Hydrogen Production From Fossil Fuels

The most optimistic projections of renewable energy technologies, however, will not produce the hydrogen demanded by societal demand. The rule of thumb for a most optimistic projection is ⅓ of the total hydrogen by renewable sources, and ⅔ from non-renewable sources such as natural gas, petroleum, coal, and nuclear.

The principal non-renewable source for hydrogen today is the reformation of natural gas. In well-designed systems, the by-product emission will be limited to carbon dioxide (CO_2). While not a criteria pollutant species, CO_2 is a greenhouse gas and most closely aligned to global climate change. In reforming natural gas for the generation of hydrogen, care is required to assure that the overall emission of CO_2 (gm/kw-hr) is equal to or preferably less than the direct fueling of a combustion engine. The goal should be a substantial reduction. But in the absence of Congressional leadership, the reality may well be a substantial increase.

To assure fuel independence and to tap a major source of hydrogen, coal is the principal candidate. Today, the use of coal as a source of hydrogen would substantially degrade the environment. Technologies are under development to reverse this consequence, and the recently announced $1B program by the President to produce an environmentally sensitive coal plant for the co-production of electricity and hydrogen is one example. Under the Department of Energy “Vision 21” program, remarkably energy-efficient and environmentally responsible designs for the co-production of electricity and hydrogen have been established for both natural gas and coal. Leadership from Congress is required to assure that these early Congressional investments in Vision 21 are nurtured and sustained to assure the development of natural gas and coal technologies that are both energy-efficient and environmentally responsible in the co-production of both electricity and hydrogen. [*Congressional Leadership Opportunity #3*]

(4) Stationary Fuel Cell/Gas Turbine Hybrid Technology

To maximize the energy efficiency promise of a hydrogen fuel economy, we must foster a key technology: the hybrid marriage of a stationary fuel cell and a gas turbine engine. The fuel cell produces electricity directly and also emits, as a byproduct, a high-pressure and high-temperature stream of water vapor and air which is used to turn a turbine generator, producing still more electricity. This so-called "hybrid" technology has a synergism of performance never before witnessed in engineering. Rather than the 30 to 40% conversion of fuel energy-to-electricity (to which we are accustomed with conventional combustion technologies), conversion efficiencies approaching 80% appear possible. In addition to the high-electrical conversion efficiency, co-production of hydrogen is a major attribute of hybrid technology. The leadership of the Department of Energy Office of Fossil Energy, under the direction of Assistant Secretary Carl Michael Smith, to develop and demonstrate this technology will likely change the manner by which electricity is generated in the future, and the manner by which hydrogen is produced.

Stationary fuel cell/gas turbine hybrid technology is a major key to:

U.S. Fuel Independence. Hybrids provide a unique opportunity to generate electricity at remarkably high efficiencies, co-produce hydrogen, and utilize either natural gas or coal with zero emission of criteria pollutants and the production of a pure CO_2-sequesting ready stream. The range of application extends from distributed generation (up to 50 megawatts) to the Vision 21 Central Power (exceeding 300 megawatts).

U.S. International Product Dominance in Future Energy Markets. Recent U.S. demonstrations with 200kW class units have confirmed the credibility of such systems. Based on these successful U.S. Department of Energy initiatives, three countries (three in the Pacific Rim alone) have been inspired to initiate multi-year development projects for hybrid technology. The United States has not established a hybrid technology road map.

Capturing the U.S. leadership in hybrid technology will require Congressional leadership. [*Congressional Leadership Opportunity #4*]

(5) Codes and Regulations.

Codes and standards for hydrogen have been developed for industrial applications of hydrogen, but not for public use of hydrogen. With the emergence of hydrogen into the public domain, attention is required to assure that codes and standards evolve in a timely fashion to assure public safety.

To place this into perspective, the public use of hydrogen divides into four principal areas: generation, distribution, dispensing, and utilization.

Generation. In the hydrogen consumer economy, hydrogen generation will occur at the site of dispensing ("on-site generation") or at large sites in remote locations (e.g., coal fired power plants, wind-farms) and the hydrogen transported by truck or by pipeline to the point of use.

For large generation sites, the hydrogen generation will occur in classical industrial zoned locations and be operated as classical industrial plants. As a result, current industrial codes and standards are likely sufficient.

For the on-site generation sites such as hydrogen fueling stations (and perhaps even home garages some day), safety codes and standards do not today exist.

Distribution. Distribution is the transport of hydrogen from the point of generation to the point of use. In the case of automobile refueling, the point of use would be the dispensing station. On-site generation, by definition, does not require distribution. As a result, no additional codes or regulations are required.

For large generation sites, transport of the hydrogen by truck or pipeline will be necessary. In both cases, codes and standards have been established. Due to the substantial expansion of the trucking (number of trucks, frequency of use) and pipelines (expanding from an existing 17 miles, for example, in southern California to hundreds of miles) associated with the hydrogen future, expanded codes and regulations will undoubtedly be appropriate

Dispensing. Dispensing ("automobile refueling") is a very public-intensive activity, particularly with the evolution of the "self-serve" era. Codes and regulations are in an embryonic stage, and requirements for standardization (for example, one "nozzle" for all vehicles; one hydrogen fuel state for all vehicles), while critical to the success of hydrogen deployment, are also in an embryonic state. "Dispensing" is the first of two areas in which Congressional leadership is immediately required to assure (1) an efficient evolution of a robust market, (2) the evolution of a safe market that is accident scarce versus accident prone, and (3) the evolution of an internationally competitive market.

Utilization. Utilization is the second of the two areas in which national leadership is immediately required for the same reasons noted above. Utilization encompasses the use by the public of vehicles fueled with hydrogen, and during many years of transition (ca. two decades) the interaction of the public driving conventional gasoline powered vehicles alongside hydrogen-fueled vehicles, and the parking of hydrogen-fueled vehicles in home garages, public parking spaces and parking structures.

Up until January 28, the codes and standards for the public hydrogen economy were emerging following the traditionally successful process of industrial working groups and professional societies. While this continues, the State of the Union acceleration of the hydrogen future creates a need for Congressional Leadership to assure that the acceleration of the otherwise multi-year process does not compromise the final product, and the engagement of individual states in the creation of codes and standards does not adversely complicate the market or place the public at risk. The President's leadership has opened the window of opportunity with the Hydrogen Initiative as outlined in the 2004 budget, but the time to act is limited and the opportunity will rapidly erode. Already, states are introducing legislation. [*Congressional Leadership Opportunity #5*]

In conclusion, I thank the committee for the opportunity to comment and to state my sincere encouragement of the committee in this important work. Regulations are often perceived as obstacles. However, a consistent, rational regulatory structure, which is predictable for industry and consumers, serves not as an obstacle but rather a well-lighted pathway to our shared energy future. Thank you for listening to my testimony today and I welcome the opportunity to respond to your questions.

Mr. BARTON. Thank you, Dr. Samuelsen.

Last, but certainly not least, we want to hear from Dr. Schwank.

STATEMENT OF JOHANNES SCHWANK

Mr. SCHWANK. Thank you, Mr. Chairman, and members of the subcommittee. My name is Johannes Schwank. I am a Professor of Chemical Engineering at the University of Michigan, and I coordinate the hydrogen-related energy activities there.

Today I would like to address the research challenges that we must overcome as we move to a hydrogen-based energy economy and touch on some of the ongoing activities at the University of Michigan. And, finally, I would like to propose a plan for better leveraging of our Nation's research universities to address this challenging problem.

Today, we are at the key formative stage of the hydrogen economy. It is important to lay a sound scientific foundation that covers a broad spectrum of hydrogen-related research issues. We must better understand the pros and cons of all our technology options before deciding on winning technologies. This can best be accomplished by more effectively engaging the Nation's research university system.

Current federally sponsored research efforts are a patchwork at best. While there have been a number of effective workshops and roadmap exercises like this hydrogen roadmap, there is no coordinated research program presently in place.

While some universities, including the University of Michigan, have received Federal support for hydrogen-related research projects, the scope and scale of these academic programs is inadequate. If we as a Nation are going to succeed in leading the transition to a hydrogen economy, then we must create a more comprehensive and coordinated university-based research initiative.

The magnitude of such a program should be on par with national science and technology initiatives like the information technology research initiative or the national nanotechnology initiative.

Three of the most important research challenges in front of us are hydrogen generation, hydrogen storage, and hydrogen utilization. I have summarized some of the major research issues for each of these three areas in my written testimony.

The first question is: where do we get our hydrogen? From fossil fuels or from water? Just like it takes money to make money, in the case of hydrogen energy it takes energy to make energy. This energy can come from a number of possible sources, such as fossil fuels, hydroelectric, nuclear energy, or solar. I submit that the jury is still out on which of these energy sources will dominate future hydrogen production.

For the next couple of decades, we can still count on our supply of fossil fuel to make hydrogen. The U.S. has an enormous infrastructure investment from oil refineries to local gas stations. We must find a way to use this existing infrastructure to make hydrogen.

At the University of Michigan, we have a DOE-funded research program to turn gasoline into hydrogen. For the long term, however, we have to turn to water as our hydrogen source. We must have a university-based research program on fossil fuel and on water-based hydrogen generation.

The second question is: how do we store hydrogen? Finding safe and economical ways to store hydrogen is critical for fuel cell powered cars. At the University of Michigan, we are working on promising new storage materials. However, we have a long way to go. We must have a university-based research program to bring the storage capacity of materials to technically acceptable levels.

The third question is: how do we make the best use of hydrogen? One of the reasons for making and storing hydrogen in large quantities is that we want to use it to power fuel cell stacks. A reasonable characterization of hydrogen fuel cell technology is that many of the engineering issues have already been solved.

We have been hearing about practical applications in this hearing. However, major obstacles remain. Current fuel cells are still very expensive and have problems with durability. Most of today's fuel cell stacks do not even come close to the reliability we expect from household appliances or car engines. At the University of Michigan, we are working on these reliability problems.

I note that hydrogen can also be burned in internal combustion engines. This lowers the emissions and gives better fuel efficiency. But further research is needed to better understand how hydrogen behaves under normal engine operating conditions.

The University of Michigan has a large automotive research center working on the utilization of hydrogen. We must have a university-based research program on fuel cells and hydrogen-powered combustion engines.

We believe that today we have a tremendous opportunity, even a responsibility, to leverage the country's research universities in partnership with industry and government to build a robust and sustainable hydrogen economy. I propose that a university-based hydrogen energy research initiative, ERI for short, be established at either the National Science Foundation or the Department of Energy.

This initiative would competitively select a group of 6 to 10 universities to undertake an integrated set of basic research and education projects. Each center would work in partnership with industry and government, and more details about this are in the written testimony.

For our Nation, it is of critical strategic and economic importance that the academic, industrial, and government sectors work together to assure that we lay a strong research foundation, permitting us to select the best pathways and technologies leading to our hydrogen-based energy future.

I thank you, and I am looking forward to questions.

[The prepared statement of Johannes Schwank follows:]

PREPARED STATEMENT OF JOHANNES SCHWANK, PROFESSOR OF CHEMICAL ENGINEERING, UNIVERSITY OF MICHIGAN

Mr. Chairman and Members of the Subcommittee: Good morning. My name is Johannes Schwank. I am a Professor of Chemical Engineering at the University of Michigan, and coordinate the hydrogen research activities within the College of Engineering. I would like to thank you for the opportunity to appear before you today to provide a perspective from the University of Michigan concerning the importance of hydrogen—based energy technologies and the important role the academic community can play in their development.

Let me begin by commending the Congress and particularly the House Subcommittee on Energy and Air Quality for its efforts to facilitate the better understanding of the science and technology challenges posed as we move to a hydrogen-based energy future.

Today, I would like to address the significant research challenges that we must overcome if we are going to see a hydrogen-based economy. I will describe some of the ongoing activities at the University of Michigan. And finally, I will propose a plan for better leveraging the capabilities of our research universities in solving the Nation's energy and environmental problems.

We find ourselves at the threshold of a worldwide shift from a fossil fuel economy to a hydrogen economy. Hydrogen-based energy, its supply and its use, will be a critical factor in economic growth, political stability, and the protection of our environment. This may be one of the greatest scientific, technical, and economic challenges our society faces in the coming decades. To bring this transition about will require significant technical advances and enormous investments in new materials, processes, and infrastructure. The consensus in the industrial and academic sector is that we must find economically and technically sound ways to produce, store, distribute, and utilize hydrogen.

At this formative stage of the hydrogen energy economy, it is important to lay a sound scientific and technical foundation, encompassing a wide spectrum of hydrogen-related fundamental and applied research issues. We must better understand the pros and cons of all our technology options, before deciding on winning technologies. A broader approach placed at the *beginning* of the product/process development spectrum is required. This can best be accomplished by using the Nation's research university system. It is critically important that the Nation invest in a basic energy research program at the university level to address the inherent fundamental research challenges. Current federally sponsored research efforts are a patchwork at best. There is no coordinated research program presently in place. Although some universities, including the University of Michigan, receive federal support for research projects that address some aspects of hydrogen-based energy research, the scope and scale of the federal effort to overcome the important technical challenges is sorely inadequate. If we as a Nation are going to see the transition to a hydrogen economy as envisioned by this hearing, securing our technical leadership position in the world, then we must create a more comprehensive and coordinated program. The magnitude of such a program should be on par with national science and technology initiatives like the Information Technology Research initiative or the National Nanotechnology Initiative. I will briefly illustrate three of the key research challenges in front of us: hydrogen generation, hydrogen storage, and hydrogen utilization.

RESEARCH CHALLENGES

Hydrogen Generation

The first question is: how do we secure an adequate hydrogen supply? Pure hydrogen does not occur naturally, and must be generated from other substances, for example coal, petroleum, natural gas, biomass, or water. This costs us some energy upfront that can come from a menu of possible sources: fossil fuel, hydroelectric or nuclear energy, solar, wind power, geothermal, or tidal energy. I submit that the jury is still out on which of these energy sources will dominate future hydrogen production.

Let's look at our options for generating hydrogen. In the near term (perhaps for the next 20 years), much of the hydrogen will be generated from fuels like natural gas and gasoline. To convert natural gas or gasoline into hydrogen pure enough for fuel cells requires rather elaborate chemical processes involving catalysts. (A catalyst is a material that by its presence helps chemical reactions to proceed more easily.) To deal with different fuel qualities and compositions available in different parts of the country, better and more durable catalysts are needed than are presently available. The discovery of these new catalysts will require major advances in materials synthesis, surface science, computational chemistry, and reactor engineering. At the University of Michigan, we have a Department of Energy-funded research program to develop better performing gasoline fuel processors to make pure hydrogen for fuel cells. We are working to find ways to decrease the size and weight of the fuel processor system by more than half to make it small enough to fit into fuel cell powered passenger cars. This goal can only be reached by developing new catalysts that are at least twice as good as the best catalysts available today, and coming up with innovative system designs. (A list of energy-related research going on at the University of Michigan is provided in the appendix.)

The alternative to processing fuels is making hydrogen from water, which is in abundant supply on the planet. You may remember your high school teacher doing an experiment called "electrolysis", where electricity is used to split water into hydrogen and oxygen. Lighting the gas bubbles coming out of the water produced a nice bang. In the long-term future, when our oil supplies start to dwindle, splitting of water may become important. To split water requires the expenditure of energy upfront and, currently, is not economical on a large scale. Major advances in technology may make this process economically more attractive. We need to work on more efficient methods to harness solar, wind, tidal, nuclear, and geothermal energy, new photocatalytic and photovoltaic materials, and improved thermochemical or biological processes. Thermochemical water splitting can be achieved using the heat from advanced nuclear reactors, but more research will be needed to fully develop these methods. It seems prudent to start now, while we can still count on fossil fuel supplies, on a coordinated research and development program in water-based hydrogen generation. Water, most likely, will become our long-term source for clean, large-scale hydrogen production.

Further, while these and other technical issues need to be addressed, one must also take into consideration the existing economic infrastructure. The U.S. has an enormous investment in hydrocarbon infrastructure, from oil refineries to local gas stations. We must find a way to use the existing hydrocarbon-based infrastructure to transition within the next couple of decades to a hydrogen economy. However, as long as we produce hydrogen from fossil fuels, we are still emitting carbon dioxide into the environment. In essence, we would simply shift the environmental pollution problem to a different location, without really solving it. One possible solution to this problem could come from research into carbon dioxide capture and sequestration, which becomes a more realistic option in larger-scale, centralized fuel processing and hydrogen production facilities.

Hydrogen storage

Once we have figured out how to make hydrogen in an efficient and economical way, the next question is how do we store and distribute it? Finding safe and economical ways to store hydrogen is arguably the key to the commercialization of fuel cell powered cars. Hydrogen can be stored as compressed gas, or as cryogenic liquid. It can also be stored or adsorbed in solid materials, such as carbon or hydride materials. However, none of the currently available methods is adequate for our technical needs. While some progress has been made over the last decade, the best hydrogen storage materials known today weigh at least twenty times more than the hydrogen they are storing. In contrast, a typical gasoline tank in a car weighs only a fraction of the weight of the gasoline inside. There is tremendous opportunity in developing new materials with larger hydrogen storage capacities. For example, at the University of Michigan, carbon nanotubes, graphite nanofibers, and new metal-organic framework (MOF) materials which show promise for hydrogen storage are under development. However, to bring the storage capacity to technically acceptable levels will require a great deal of fundamental research. To develop practical solid-state hydrogen storage materials requires a much better fundamental understanding of the storage mechanisms, materials properties, and synthesis and manufacturing methods.

Hydrogen utilization

Hydrogen is attractive, since it can be efficiently and cleanly converted to electrical and thermal energy. One of the reasons for making and storing hydrogen in large quantities is that we want to use it to power fuel cell stacks. A reasonable characterization of hydrogen fuel cell technology is that many of the engineering issues have already been solved. There are several different types of fuel cells in existence, classified according to the type of membrane material used. The operational temperature range of each of the fuel cell types is limited by the type of material used in the membrane. You are hearing about practical applications in this hearing. However, major obstacles remain. Many unsolved fundamental research problems are in front of us, falling into the broad range of materials science, electrochemistry, and electrode catalysis. Current fuel cells are very expensive, but have problems with durability. For example, we expect a typical household appliance to last for many years without maintenance. Unfortunately, most of today's fuel cell stacks do not even come close to this expectation of reliability, primarily due to materials limitations. The catalysts on the electrodes are very sensitive to impurities in the hydrogen. The fuel cell membranes, depending on type, have their own, inherent weaknesses limiting their useful life. Fuel cell stacks pose challenging sealing problems. Hydrogen has a tendency to leak through most materials. These challenges represent a significant opportunity for materials and catalysis research. At the University of Michigan, we are working on several of these materials challenges, to develop a better understanding of failure mechanisms, and to come up with better membrane materials and electrode catalysts.

Besides use in fuel cells, hydrogen can be burnt in internal combustion engines. However, since hydrogen has properties quite different from gasoline or diesel fuel, more research is needed to better understand how hydrogen behaves under engine operating conditions. The University of Michigan has one of the largest automotive engineering research centers in the country and is conducting research on the utilization of hydrogen in combustion engines. Laying the research foundation for using hydrogen in today's transportation systems is extremely important because so many jobs and industries are dependent upon these systems. Use of hydrogen in internal combustion engines may, in my opinion, facilitate the evolution to a hydrogen economy.

Given these formidable research challenges, I submit that the verdict is still out which of the many energy utilization technologies (internal combustion, fuel cells, batteries, or hybrids) will power stationary or mobile systems in the future.

A PROPOSED UNIVERSITY-BASED ENERGY RESEARCH INITIATIVE

We believe that today we have a tremendous opportunity, even a responsibility, to leverage the country's research universities in partnership with industry and government to overcome the obstacles to achieving a robust and sustainable hydrogen economy. What is needed is a university energy research initiative specifically created to capitalize on the energy research expertise residing in our Nation's universities. This initiative should be on par with such national science and technology initiatives as the National Nanotechnology Initiative and Information Technology Research Initiative. It is easily as important as these initiatives and, I would argue, more important. While the DOE, the DOD and the NSF all have some programs to support individual or groups of university investigators, there is no strategically coordinated national initiative in place that engages the country's research universities in the transition to a hydrogen energy economy.

I propose that a university-based Energy Research Initiative (ERI) be established at either the National Science Foundation or the Department of Energy. The primary focus of the ERI would be hydrogen-based energy systems. Regardless of the federal agency home, basic research funds from all of the federal agencies promoting energy research should be used to supplement the program. The Energy Research Initiative would competitively select a group of 6-10 universities across the country to undertake an integrated set of basic research and education projects focusing on energy issues. Each center would work in partnership with industry and government.

It is extremely important that promising developments and technologies move quickly to implementation. To promote this, we propose that ERI basic research activity be supplemented by "technology accelerator" seed funding to encourage small businesses, in partnership with universities, to further develop promising technologies. Large companies could also play a role in this but would be asked to cost share their role in the activity.

Finally, states can play a role as well by augmenting the federal funding for the ERI with a state-funded economic development program that would support the development of small energy-focused businesses and facilitate their linkage to larger companies within the state.

I would recommend that $10M in federal funding be allocated to support each of the centers on an annual basis. Approximate breakdown would be: $8M for basic research and education, $2M for technology accelerator projects (not including any state contributions). Taking an approach similar to the National Science Foundation Engineering Research Center program, each Center could be funded for a five-year period with an additional five-year renewal based upon performance.

I strongly believe that a university-based Energy Research Initiative that broadly focuses on the Nation's energy research and education needs will provide significant leveraging of federal research dollars. Basic research carried out in research universities provides the foundation for the research, development, and engineering continuum. Importantly, it facilitates technology transfer by moving new discoveries and innovations from the laboratory to the market place, and encouraging industry partnerships to develop promising technologies. For our Nation, it is of critical strategic and economic importance that the academic, industrial, and government sector work together to assure that we lay a strong research foundation, permitting us to select the best pathways and technologies leading to our hydrogen-based energy future.

Appendix

SELECTED ENERGY-RELATED RESEARCH PROGRAMS AT THE UNIVERSITY OF MICHIGAN

1. FUEL PROCESSORS FOR PROTON EXCHANGE MEMBRANE FUEL CELLS
2. ADVANCED CATALYSTS FOR HYDROGEN GENERATION
3. THERMAL TRANSIENT RESPONSE OF PROTON EXCHANGE MEMBRANE FUEL CELLS
4. MICRO-FUEL CELLS AND NOVEL ELECTROCATALYSTS
5. COORDINATION OF HYDROGEN AND AIR FLOW FOR TRANSIENT CELL LOADING
6. SYSTEMATIC DESIGN OF PORE SIZE & FUNCTIONALITY FOR METHANE AND HYDROGEN STORAGE APPLICATIONS IN FUEL CELLS
7. DEVELOPMENT OF HYDROGEN INFRASTRUCTURE FOR FUEL CELL VEHICLES
8. MICROELECTRONIC GAS SENSORS AND GAS STORAGE MICRO-RESERVOIRS
9. HYDROGEN STORAGE IN CARBON NANOTUBES AND CARBON NANOFIBERS
10. HOMOGENEOUS CHARGE COMPRESSION IGNITION (HCCI) ENGINE RESEARCH CONSORTIUM
11. SIMULATION-BASED DESIGN AND DEMONSTRATION OF NEXT GENERATION, ADVANCED DIESEL TECHNOLOGY
12. ADVANCED HYBRID PROPULSION SYSTEM COMPONENT MODELING AND POWERTRAIN INTEGRATION
13. DEVELOPMENT OF A PRESSURE REACTIVE PISTON FOR IMPROVED FUEL EFFICIENCY AND REDUCED EMISSIONS IN SI AND CIDI ENGINES
14. ADVANCED BATTERY SYSTEMS AND MODELING FOR HYBRID ELECTRIC VEHICLES
15. HYBRID ELECTRIC VEHICLE SYSTEM DESIGN OPTIMIZATION
16. POROUS NANO- AND MICRO-ARCHITECTURED MATERIALS: BATTERY APPLICATIONS
17. SAFETY ISSUES FOR HIGH POWER LI ION BATTERY ANODES
18. THE UNIVERSITY OF MICHIGAN CENTER FOR INDUSTRIAL ENERGY AND ENVIRONMENTAL ANALYSIS
19. IMPROVING PLATE GLASS QUENCHING TECHNOLOGY TO SAVE ENERGY
20. DEVELOPMENT OF A HIGHLY PREHEATED COMBUSTION AIR SYSTEM WITH-WITHOUT OXYGEN ENRICHMENT FOR METAL PROCESSING FURNACES TO SIGNIFICANTLY IMPROVE ENERGY EFFICIENCY AND REDUCE EMISSIONS

Mr. BARTON. Thank you, sir. And I want to thank the panelists for your excellent testimony. This really gives us kind of a breadth of analysis about where the research is and where the industry is.

The Chair is going to recognize himself for the first 5-minute questions.

I want to go to you, Dr. Samuelsen. You mentioned that your fourth point was somewhat revolutionary, some sort of a hybrid hydrogen turbine that had efficiencies, if I understood correctly, of about 75 percent. Can you compare that to a combined cycle natural gas turbine today, what the efficiencies are?

Mr. SAMUELSEN. Mr. Chairman, the combined cycle would be approaching 50, 55 percent. So it is a jump of 20 percentage points, 20, 25 percentage points.

Mr. BARTON. And would that be the same application that this research turbine that you have talked about would compete in the large base station powerplant generation sector?

Mr. SAMUELSEN. It would be the same application in the center power. But in addition to that, it also has a very substantial application in the distributed generation market, the 100 kilowatts to 50 megawatt arena as well—a broader application.

Mr. BARTON. Okay. Mr. McCormick and Mr. Preli, you all were pretty optimistic. You all were kind of "pedal to the medal, gung-ho, let us go for it." But Mr. Vesey was a little more "we ain't making any money, and we don't think we are going to get into this if we can't make some money." So what do you two guys need to do to Mr. Vesey to get him to show a little more enthusiasm for this program?

Mr. PRELI. I think maybe our enthusiasm stems from the fact that we have been working on this for 40 years, many times alone. And now there is a much larger effort—in fact, much of it is outside of the United States, and perhaps now is the timing between the technology that is being pulled by the automotive industry that also has applicability in other areas like stationary and fleet applications.

So I think we are optimistic, because with so many people working on it, and so much investment going into it, progress will be made. Key issues, however, remain I think as we both pointed out. And that is, if you are moving toward a hydrogen economy, you need to have the hydrogen. And perhaps that is where some of this optimism needs to be tempered, because even if the technology is there, and even if the cost comes down, if you need to operate on hydrogen, then you still need to stimulate that and have hydrogen in your economy.

What I will add, though, is that the first applications using stationary powerplants, which have been in service now for over 10 years, run directly on natural gas. You get around that infrastructure problem. You trade some of the powerplant efficiency, but you don't need the hydrogen. You can run them right on natural gas. You convert it right inside the fuel cell powerplant.

Mr. BARTON. Mr. McCormick, what do we need to do to make it possible for Mr. Vesey to make some money so that they will make the investments to create the hydrogen?

Mr. MCCORMICK. Well, a couple of general comments. As I mentioned, the progress on the fuel cell and propulsion technology is extraordinary. But very importantly, this notion that we can build vehicles that consumers will want to buy. And I think any prudent car company or any prudent fuel company ought to pay attention to the consumers, No. 1. And I think we are convinced that we will be able to do that.

But the second thing—and I don't want to speak for ChevronTexaco or the energy companies—but there is a huge amount of capital that has to be mobilized in order to make this transition. We are faced between us with this chicken and egg issue that if we put the vehicles out there, is there an infrastructure? Or, conversely, if the infrastructure is there, will the vehicles be there?

Particularly in the infrastructure issue, a lot of the cost of hydrogen that you have heard described today is attributable to return on capital. And so the issue of how actually capital is made available and how there is taxation or policies around that will be crucial, I think, to this transition.

Mr. BARTON. Mr. Vesey, do you want to comment on that?

Mr. VESEY. Well, I didn't mean to come across as not optimistic on this, Mr. Chairman. What we have done is, in focusing on the business aspects of this, we have looked at alternative business models that might make this space attractive.

So I think one of the ones you have heard some reference to here that we are very supportive of is a dual use, so to speak, of the hydrogen, where you have either a fleet, that you are also powering a fleet as well as filling some vehicles on the side, or whether you are providing distributed generated power, and then also fueling vehicles at the same location.

So we are very excited about the space, but are very focused on proper business models for that.

Mr. BARTON. Okay. Dr. Preli, who else is involved in this technology in terms of creating and manufacturing the fuel cells? Who is our international competition?

Mr. PRELI. I think internationally it depends upon what market you are talking about. But in the small residential size, I think the major competition is coming from Japanese companies. There is a large effort in Japan to develop small systems. I think in fleet applications our No. 1 competition may be from Europe where they have a very large demonstration program looking at 30 buses in the near term in European cities.

And then, in automotive, Japanese car companies like Toyota are developing their own technology. In the United States, GM and ourselves are developing technology for automotive. In Europe, DaimlerChrylser is one of the leaders.

Mr. BARTON. Okay. My time has expired.

The gentleman from Maryland.

Mr. WYNN. Thank you, Mr. Chairman.

There seems to be a consensus that one of the first stops along this pathway is stationary fuel cells. Is that the consensus? What does the government need to do to facilitate the expansion of stationary fuel cells?

Mr. MCCORMICK. One of the issues with stationary fuel cells is they are, by and large, not big multi-megawatt baseload machines. They don't replace a nuclear powerplant, for example. And so when we go to place those distributed generation units, we have to start thinking about interconnection standards.

And one of the issues is: how do you get the distributed generation systems put on the grid in various locations? And it turns out that the decisions around that are all local with public utility commissions and things. And so as we talk about rolling this technology out, we face an uncertain market, at least in the United States, because we are at the whims of each local community. That is not necessarily true in Japan where they are actually uniform in those codes.

Mr. WYNN. Could you send me something on that? Just a brief statement of that particular issue——

Mr. MCCORMICK. Absolutely.

Mr. WYNN. [continuing] to help us with it. Now, there seemed to be less agreement about whether the next step should be fleet vehicles in terms of buses, if I am understanding you right, versus light trucks. Is there a difference of opinion on that subject? I don't want to create one if it doesn't exist, but I have heard some people talking about buses.

I know Ms. Rips was very interested in bus development, but I also heard maybe light trucks would be better. Mr. Vesey?

Mr. VESEY. Yes. Thank you, Congressman. I really don't think so. I think it is that you have enough vehicles that when you are generating the supply of hydrogen there is adequate use. So the term "fleet" could be buses, it could be light-duty vehicles. From our standpoint, it is that there is enough to use the hydrogen on a daily basis.

Mr. WYNN. To what extent would a government fleet commitment, either trucks or buses or vehicles, passenger vehicles, facilitate the commercial growth? Mr. McCormick?

Mr. MCCORMICK. I think it is very, very important. What we don't want is demonstrations that leave no legacy. What we want are real commercial transactions where, in fact, we sell something. And most importantly, when we prepare those fleets, pick it in places where the infrastructure grows naturally. So some of the post office kinds of initiatives, the right selection of some DOD initiatives, would be very good, but there may well be others.

What we want to do is pick the application to make sure that there is public refueling involved in that application, and then you get the dual leverage. The people can invest in the fueling station knowing that there is going to be usage.

Mr. WYNN. So the public refueling would be the key there?

Mr. MCCORMICK. Yes.

Mr. WYNN. Okay. Now, I was looking at a piece from something called India Car that said that Ford is getting ready to sell 50,000 units of passenger vehicles to Germany by the year 2010. Could anyone respond to that? Is that likely to happen, or is that specious?

Fleet News reports that Ford is planning to sell a mass-produced hydrogen fuel cell vehicle in the German fleet market. The reports says that from 2010 Ford believes it will be manufacturing at least 50,000 units of the vehicle per annum. Dr. Franz Martin Dubbell, Ford's Vehicle Alternative Power Trains Market Manager, told Fleet News at a media briefing and auction that Ford is planning to run its first vehicles with small fleets in Germany and California in 2004, with full launch slated for 2010.

Is this smoke, or is this real? Coming from the competitors.

Mr. MCCORMICK. Well, I certainly wouldn't want to speak for Ford, but I think those are not unrealistic kinds of numbers. One of the things when we think about where vehicles are launched worldwide, and I think this is very important to the discussion, we have to think about——

Mr. BARTON. Look around at the audience. They are smiling right now.

Mr. MCCORMICK. We really have to think about where internationally are the codes and standards and the infrastructure going to happen. And so it may well be Europe, it may well be Japan, it may well be the United States. And I think we have to see how that develops.

Mr. WYNN. With respect to codes and standards, because several witnesses mentioned it as well as Dr. Garman, can the industry help us—well, I know there is a self-regulation concept that is sometimes called into question. But can they at least get us started on the format or the template, if you will, rough template or draft template or something relative to codes and standards, so that the committee could begin to look at that issue in more detail and provide us with the input?

Mr. VESEY. Yes, sir. I think the hydrogen roadmap that Mr. Garman referred to, codes and standards was a big piece of that, and the industry is working very closely with the DOE to get the proper codes and standards started.

Mr. WYNN. Okay. Would you submit that to this committee as well?

Mr. VESEY. Certainly.

Mr. WYNN. Okay. Thank you.

My time is up. Thank you.

Mr. BARTON. The gentlelady from California.

Ms. BONO. Thank you, Mr. Chairman. Mr. Chairman, I actually had the opportunity to drive a fuel cell bus, and it was a scary moment, not for me as much as for everybody else on the road I think at that time. But I want to thank, again, SunLine for being such a leader in all of these future technologies.

But my questions for Catherine really comes—or Ms. Rips, excuse me—I have known her way too long. People think of the desert, they think of all of our windmills and our solar capabilities. Can you explain a little bit how much solar and wind you are currently using in the production of your hydrogen?

Ms. RIPS. Yes. Thank you for the question. We have been generating hydrogen using solar power for the last 3 years at SunLine. We are currently using it to power an electrolyzer. I know Mr. Garman was talking about that as an option earlier, and I think that probably the biggest deterrent to the use of that technology is just the cost of it.

And so, you know, there is a school of thought that if there was simply more orders placed for those kinds of systems that the cost would come down. So I know you had asked what the government could do to help, and perhaps being a purchaser of those systems might be something that would work.

We are also involved in a wind project. The desert does have a lot of wind generation. The wind belt is the Banning Pass there. And we are working with South Coast Air Quality Management District and some other partners to do a project that should come online in a couple of months where we will be using power directly off of a wind turbine to generate hydrogen from an electrolyzer.

So we will have a much better idea of what the relative costs are once that project is operating. But that, of course, would be the end goal.

Ms. BONO. Thank you. When I drove the bus, I had an interesting question, too, and perhaps it is an offshoot of the direct hydrogen question. But when you deploy a bus that is a million dollar bus or so, how does the public feel about these buses being on the street? What has their reaction been, other than my driving?

And is the insurance—I mean, how does the insurance model work when suddenly there is a liability factor? And if somebody were to take out one of these million dollar buses, can you explain to me how I guess the integration with the public is going to run with that on the street?

Ms. RIPS. Okay. Well, we think that it is very important to bring the public along in any conversion to an alternate fuel. So we really stress education and outreach and do activities that put our vehicles out into the community, so that people can get used to them. And we did definitely publicize the fuel cell bus and let people know that it was going to be out on the street.

Prior to it actually going into revenue service, we had a different fuel bus out there just for a short time. And when we advertised it, people literally lined up to ride it. They were so excited about it. And we had comments constantly from our riders. We put the thunder power bus that Congresswoman Bono is referring to in revenue service for over 3 months, and passengers would call us and talk to the drivers about it and actual call the switchboard. And they are very impressed with it.

We used the opportunity to educate them about the benefits of it, because we feel that, you know, one of the things that transit does is give you basically a mobile billboard for the technology. And by using the outside of the bus, and also by using the inside panels on it, you have an opportunity to educate a captive audience and let them know what the benefits of hydrogen fuel cell technology are.

And what we have found is that the more you educate them, the more they appreciate what you are doing for the environment and also for their health. So it is a great vehicle to educate while it is actually transporting people.

Ms. BONO. Thank you.

Dr. Samuelsen, also, can you explain a little bit—again, the safety factor still I think rides on people's minds when you talk about hydrogen. But are hydrogen fuel cell vehicles able to drive through tunnels currently?

Mr. SAMUELSEN. They are indeed able to drive through the tunnels currently. But it is in the absence of any regulation to prohibit them from doing that.

The area where perhaps there is the largest challenge in the safety aspect—I think Assistant Secretary Garman addressed the safety aspects very well in terms of the diffusivity of the hydrogen relative to gasoline and the relative more safe conditions of being able to operate a hydrogen car compared to a gasoline car. But he also——

Ms. BONO. So the garaging of this vehicle is going to be the same as we have today?

Mr. SAMUELSEN. Well, that is the point I wanted to get to. There was a Congressman who referred to the NASA incident, and Assistant Secretary Garman referred to it probably being an enclosed space. And we do have, with public use, enclosed spaces—our garage, public parking structures, and other private parking structures.

How those are established with appropriate sensing, if that is what is needed, appropriate ventilation, if that is what is needed, has not been addressed and will need to be because certainly we want to be able to garage our car as we do today with our gasoline car.

Today we put a car into the garage with 20 gallons of gasoline, have natural gas flames about with the clothes dryer, the water heater as examples, and we need to evolve from that experience and confidence in safety with the current infrastructure to one that equals that with hydrogen as well.

Ms. BONO. Thank you. I asked that question the other day. I was at a parking structure over by the Pentagon, and there was a car fire two levels down. And so you kind of really have to ask the question.

But I know that my time has expired. So thank you, Mr. Chairman. Keep going?

Mr. BARTON. You can keep going. You didn't questions the first round, so——

Ms. BONO. Well, thank you. I have got to go through my list.

Back to Ms. Rips, then, you were among the first public transit agencies to convert your fleet entirely to natural gas. Do you see the conversion of other agencies going as smoothly as yours did and as timely?

Ms. RIPS. I am sorry. Could you say the last part of that again?

Ms. BONO. You see, say when we do move to fuel cell entirely to your bus fleet—in the future, obviously—do you see the conversion going as well as other companies have followed with natural gas?

Ms. RIPS. Well, that is a very good question. And, you know, as I mentioned in my statement, we think that training has everything to do with how the conversion process goes. So when we converted to natural gas, we had actually trained every person on our staff, including the receptionist, I mean everybody, as far as the properties of natural gas and the benefits of it and the different things that they had to be aware of.

We have done the same thing with hydrogen. We actually had the Schatz Energy Research Center at Humboldt State University come down and put on a series of seminars for everybody at our transit agency and our board members to educate them. We have worked with a number of partners, including a university system and our community college, to create the first curriculum for hydrogen fuel cells and related technologies.

And we think that if people are properly trained and make a commitment to training and participate in the education process, we would like to see this ideally start at the high school level and go through community college and college-level courses, so that technicians are trained, that there is a skilled workforce in place. We don't think that there will be any problems that are not fairly easily solved.

And I am sorry, I didn't answer your question about insurance. Liability insurance is definitely an issue that needs to be resolved. Like the codes and standards, it is different everywhere. And we were able to cover you on our policy, so you were safe driving. But it is definitely an issue that needs to be looked at.

Ms. BONO. Thank you. I yield back, Mr. Chairman.

Mr. BARTON. We are now going to just have some wrap-up questions. And all members that wish to—we are not going to put the clock on. I have got two or three questions, and I think Congressman Wynn may, and Congresswoman Bono.

Ms. Rips, you obviously—your community has put a lot into this program. But when Congresswoman Bono was talking about the million dollar bus, there are not many communities that would have public transit that could afford to put into service million dollar buses if they have to even come close to breaking even.

So, I mean, again, your community is to be commended for taking the lead, but I would think that you are a fairly affluent community, somewhat above the national average in income levels, and probably above the national average in willingness to bear an extra burden to show progress on the environmental front. Is that correct or incorrect?

Ms. RIPS. Well, actually, it is an interesting community. There are nine cities in the Coachella Valley and several unincorporated areas. And while we do have a couple of cities that among the wealthiest in the United States, we also have several communities that are among the poorest.

We have really an inordinate number of very poor residents, unfortunately. So it is true, and it is not true. I think that what you are seeing in the Coachella Valley is really commendable political leadership, and it is nothing but the leadership of our elected officials that caused our transition.

And it was their commitment to the program and their desire to see a clean environment——

Mr. BARTON. Well, what kind of, in the best case, profit do you make? Or, in the worst case, how deep is the deficit?

Ms. RIPS. Well, let us say that we look forward to the day when the buses only cost a million dollars. That was really—that is low for what they are costing these days. But, you know, as UTC pointed out, the cost of that technology is coming down. And we realize that—we are working with the FTA on some things, and their goal is to see—because of the increased efficiency in a fuel cell bus, their definition of commercialization is when a fuel cell bus costs twice what, for instance, a natural gas bus would cost. That would bring the cost down to about—or to a diesel bus. That would bring it down to about $600,000. So——

Mr. BARTON. And compare that to—what does a natural gas bus or a diesel bus cost today?

Ms. RIPS. About $300,000. So they are saying if a fuel cell bus costs $600,000 that—because of the increased efficiency it would be considered equal.

The community has put a lot into it. We think that there are a couple of more generations of technology, of R&D on the technology, needed to get it down to the point where it is compatible on a cost basis. And that is the reason why we advocate a limited number of demonstration projects with multiple generations, because——

Mr. BARTON. I am very positive I don't want——

Ms. RIPS. [continuing] we clearly believe that we will get there.

Mr. BARTON. I am very positive on which you are doing. I just—I am not sure that my community of Ennis, Texas, would be willing to take the intangible satisfaction as opposed to the less intangible but more taxpayer-friendly existing technology that is available today. So——

Ms. RIPS. Well, and I think that is exactly the point, that the technology is not suited for every application at this point in time. And what we are trying to do is help it get to the point where it is. If we are successful in our efforts and working with our partners, you know, in perhaps 10 years it will be affordable for Ennis, Texas.

Mr. BARTON. Yes. Thank you.

Dr. Samuelsen? And then I have a question for Dr. Schwank.

Mr. SAMUELSEN. I just wanted to comment that I think one looks to mass volume production to bring down the price at some point in time. But what is not fully appreciated is the strategy among many manufacturers—and Mr. McCormick alluded to this with respect to using automobile technology and distributed generation—but it is also to use automobile technology in the outfitting of the bus with the fuel cell stack.

So you will see fuel cell buses evolving that basically are operating on two automobile fuel cell stacks benefiting on the mass production that will eventually result and have this commonality between the automobile application and the bus application, rather than thinking of them as separate, distinct applications.

Mr. BARTON. Okay. And, Dr. Schwank, you talked about a university-based research component, 6 to 10 universities around the country. Is there any formal organization that has been developed among the universities, the research universities, to do that, or is that just a concept that you wanted to put on the table?

Mr. SCHWANK. Thank you, Mr. Chairman. Our proposal recognizes that the task before us is enormous. I would compare it in terms of technological challenge almost to the moon shots. We have an incredible talent pool in our universities, but universities—the university research is not coordinated so that you can bring the powerful synergism together.

The coordination of this has to be done by bringing together a partnership of the industrial sector, the government sector, and the academic community. We would be happy to provide an initial blueprint, some first draft, for further discussion, and then invite industry and government into—work on this and shape it. I think the task is too big for one individual constituency to do it all by themselves.

Mr. BARTON. Well, we would appreciate that. Just be sure that University of Maryland and Texas A&M University and University of California at Palm Springs are included in the discussion phase.

Mr. SCHWANK. We will certainly take it into advisement.

Mr. BARTON. This is my last question, and then if any other members have a question.

Mr. McCormick, what is the best case timeline—the Ford Motor Company people apparently have issued a press release that they are going to sell 50,000 hydrogen cars in Europe by the year 2010. I have been out to Detroit. I have been to your test facility several years ago with the Vice President.

If everything that could go right did go right, you know, how soon does General Motors see a retail vehicle, a consumer vehicle, that is available in the showrooms around the country?

Mr. MCCORMICK. Well, I think we in Ford, and actually most of the auto companies, are looking at that 2010 date. A combination of a couple of reasons. We think the technology is moving at that kind of a rate that justifies looking at that date. And quite honestly, if we are not talking about a date like that, then probably as a business I am spending too much money on it.

So we have to see it getting into the field in that 2010 to 2015 timeframe to sustain the kind of investment that we are putting into it.

Mr. BARTON. So we are talking about let us get moving right now. And finally—I said that was the last question—but, Mr. Vesey, when you were in my office you talked about the need to develop a technology for onboard storage of hydrogen that wasn't yet in existence. And you talked about your best case was some sort of, if I understood you correctly, a solid-state storage model. Could you very briefly elaborate on that?

Mr. VESEY. Yes. All it was referring to—the current technologies are high compressed gas form or liquid, which is at a very cold temperature. And there are experiments going away with metal hydrides, which if you can get the weight percent up to where it will give the vehicle a proper range it is not high pressure and it is ambient temperature. So it is a little more palatable from a consumer standpoint.

Mr. BARTON. And is that something that we need to encourage the Federal Government to invest more research dollars in, perhaps through Dr. Schwank's university-based research program?

Mr. VESEY. I think we would all agree that storage is the key issue here, and any recommendations in helping those technologies would be good.

Mr. BARTON. Okay. Congresswoman Bono or Congressman Wynn, any final comments? Either one of you?

Ms. BONO. Just one, Mr. Chairman, just to help my friend out. When you mentioned the wealthy, affluent Palm Springs area, our No. 1 industry is actually agriculture, and people believe it is a much different district than it is. And I know you have talked about coming out to visit, and I want to reextend my invitation for you to come out and——

Mr. BARTON. We are working on that.

Ms. BONO. Thank you. I know that you are.

Mr. BARTON. I am looking forward to it, actually.

Ms. BONO. I look forward to your visit. And with that, I yield back my time. Thank you.

Mr. BARTON. Mr. Wynn?

Mr. WYNN. Mr. Chairman, I just want to thank you again for putting this hearing together. I learned a great deal. I also want to thank you for your support for the University of Maryland. That is duly noted.

Thank all of the members of the panel. I will be contacting you individually, because I do have a couple other questions.

Thank you, Mr. Chairman.

Mr. BARTON. We, again, appreciate this panel. There may be written questions for the record. We hope that you will reply expeditiously. We appreciate your time and testimony and look forward to working with you.

This hearing is adjourned.

[Whereupon, at 12:45 p.m., the subcommittee was adjourned.]

[Additional material submitted for the record follows:]

PREPARED STATEMENT OF THE AMERICAN PETROLEUM INSTITUTE

The U.S. oil and natural gas industry is committed to meeting the nation's future transportation fuel needs. Since its beginning, the industry has been in a constant state of change, working to better serve its customers and a growing nation. Relying heavily on advanced technology, the industry has provided improved products to Americans with a steadily reduced impact on the environment, and we will maintain this commitment in the future.

We believe that competition and the resulting push to innovate will mean that our children and grandchildren will be driving vehicles using fuels that, together, are safer, cleaner, and more efficient than ever. These improved cars and trucks may well be propelled by something other than today's internal combustion engine, whether it is an advanced version of that engine or electric hybrids or fuel cell vehicles. We believe the 21st century will be an exciting new era for personal transportation.

While we expect conventional hydrocarbon fuels will remain the dominant energy source, at least through the mid-century, the oil and natural gas industry is committed to providing the fuels for the nation's transportation needs regardless of the fuel type. Future automobiles may be based on a variety of advanced technology engine-fuel systems, including hydrogen-powered fuel cells. At least initially, all of these systems will likely rely heavily on hydrocarbon fuels either directly or indirectly. These advanced fuel/vehicle systems should be allowed to compete with each other in the marketplace and on a level playing field.

The Role of Hydrogen in Meeting Transportation Needs

The American Petroleum Institute appreciates this opportunity to present the views of its member companies on the role of hydrogen in meeting the transportation needs of American consumers.

In his State of the Union Address, President Bush announced a Hydrogen Initiative to hasten the development of hydrogen-powered fuel cells in motor vehicles. API believes that fuel cell vehicles are an exciting new technology that could figure prominently in America's transportation and energy future.

As we understand the program, the Hydrogen Initiative will focus on pre-competitive research aimed at advancing the technology to produce, store, distribute, and deliver hydrogen for use in fuel cell vehicles and electricity generation. The Administration has indicated that the Hydrogen Initiative will complement the FreedomCAR initiative, which supports pre-competitive research in advanced automotive technologies for the mass production of a full range of affordable vehicles, including fuel cell vehicles.

At the outset, we must all recognize that development of hydrogen as a viable transportation fuel source will take time. The U.S. Department of Energy's National Hydrogen Energy Vision and Roadmap reports envision a path for hydrogen development that would span between three and four decades. It is important to keep this timeframe in mind and recognize that hydrogen research will require a long-term commitment. We should also recognize that major technological breakthroughs are required before hydrogen can become a viable fuel source.

The increased national interest in hydrogen as a transportation fuel is understandable. Hydrogen exists in nearly unlimited abundance and, when used in a fuel cell vehicle, generates zero emissions. However, it should be noted that hydrogen only exists in combination with other chemical elements, and significant energy and costs are required to produce, store, distribute and deliver hydrogen for use in fuel-cell vehicles.

API believes that, in evaluating the pros and cons of any fuel/vehicle system, it is vital to undertake a "well-to-wheels" analysis of the entire system. The "well-to-wheels" approach considers energy use and emissions for both "well-to-tank" (i.e., production and distribution of the fuel) and "tank-to-wheels" (i.e., use of the fuel in the vehicle). When using this approach, different fuel/vehicle systems can be analyzed on a comparable basis. The internal combustion engine is the benchmark against which the progress of emerging advanced fuel/vehicle systems should be measured.

In considering future transportation fuel needs, there are near- and mid-term options for increasing fuel use efficiency and reducing emissions. Alternatives include hybrid engine systems—a combination of an electric motor and gasoline or diesel engine—and advanced gasoline and diesel engine technologies. The rate of market penetration for hybrids will likely depend upon price and performance; however, it should be recognized that gasoline hybrids are currently in the marketplace and numerous auto manufacturers have announced plans to introduce a variety of additional hybrid models over the next few years. Ongoing research and development continues to focus on reducing the component cost of hybrids. All of this suggests that there is substantial promise for hybrid technology playing an important role in improving efficiency and lowering emissions.

When comparing greenhouse gas emissions on a well-to-wheels basis, a number of advanced vehicle and fuel options compare favorably with today's gasoline internal combustion engine. Diesel engines, gasoline and diesel hybrids, on-board gasoline reformer based fuel cells (i.e., systems where hydrogen is produced on-board the vehicle via extraction from gasoline-like fuels), and fuel cell vehicles powered by hydrogen produced from natural gas all have lower greenhouse gas emissions. In contrast, hydrogen produced via electrolysis of water using electricity from typical U.S. sources has very high greenhouse gas emissions. Thus, there are a variety of advanced systems that have the potential to lower greenhouse gas emissions, but none of these systems result in 'zero' greenhouse gas emissions.

To address the areas mentioned above, API member companies have undertaken substantial research activity in advanced technologies such as hydrogen production and storage, combustion fundamentals, exhaust aftertreatment, and improved hydrocarbon-based fuels that enable lower emissions and higher efficiency. Much of this work is done in close collaboration with automobile and engine manufacturers, the government and other partners.

Technological Breakthroughs Needed for Hydrogen and Fuel Cell Vehicles to be Viable

Technological breakthroughs are required to reduce fuel cell vehicle costs and to reduce production, distribution, delivery and storage costs of hydrogen for the system to be competitive against the ever-improving performance of advanced internal combustion engine and hybrid vehicle systems. Moreover, increased use of hydrogen as a transportation fuel involves other challenges, including safety, the potential need for a new distribution infrastructure, and a need for approaches that address potentially increased emissions due to hydrogen production.

Cost Reduction and CO_2 Emissions Need To Be Addressed

Breakthroughs are needed to lower the cost of fuel cells and fuel cell vehicles. For example, the cost of the fuel cell stack needs to be reduced substantially to compete with a conventional powertrain. The cost of fuel cells has dropped by about a factor of 100 over the last 10 years, but automakers say that costs must still be reduced by more than a factor of 10 for the technology to become competitive.

Like electricity, hydrogen is an energy carrier, not an energy source. To succeed in the market, hydrogen will need to be produced in large volumes at reasonable cost. But, without a major breakthrough in production technologies, most hydrogen would likely continue to be produced from natural gas, the most affordable source of hydrogen with current technologies. However, the United States is short of indigenous natural gas and, in order to provide large amounts of hydrogen, access to the potentially large natural gas reserves on government lands and/or imported LNG will be needed. Hydrogen production is, therefore, an important research area.

If hydrogen were made from natural gas or other fossil fuel sources, then CO_2 would also be generated as a by-product. If low greenhouse gas emissions are to be achieved in that scenario, it would be necessary to separate, capture and store the CO_2 generated (i.e., CO_2 sequestration). Thus, breakthrough research focusing on CO_2 separation, capture and storage methods is also important. If, on the other hand, sufficient electricity could be generated by renewable or nuclear technologies to make hydrogen from water, then CO_2 sequestration technologies would be less important. However, cost reduction breakthroughs in renewable and nuclear technologies would then be needed.

Distribution Infrastructure Issues Need To Be Addressed

Hydrogen distribution could take one of two forms: pipelines or specially designed, very-low temperature tankers. Currently, high-pressure tankers are limited in their energy-transporting volume. Because hydrogen has a much lower energy density than gasoline, it would require 19 hydrogen tankers to carry the energy value of one gasoline tanker assuming the hydrogen and gasoline tankers were of similar size. On the other hand, pipelines could move much greater volumes, but existing natural gas pipelines are not suited for hydrogen and new ones would be required. Regardless of whether hydrogen is distributed via retrofitted pipelines or new dedicated pipelines, technological issues need to be addressed. For example, leak detection technology is needed which requires research in the sensors and odorants areas. Breakthroughs in new materials and improvements in automated welding techniques are needed to lower pipeline costs. Improvements in compressor technology including seals are needed to improve compression efficiency and reduce costs. Improvements in hydrogen liquefaction technology are also needed to lower costs and increase energy efficiency.

Developing a distribution infrastructure for hydrogen for direct fuel use would be costly. However, there are alternatives such as using the existing hydrocarbon fuels infrastructure and extracting the hydrogen with an on-board reforming system or producing the hydrogen at the retail station. These alternatives would help resolve safety and infrastructure issues needed for the initial introduction of fuel cell vehicles, provide time to advance breakthrough research, and provide a 'bridge' to hydrogen should breakthrough research be successful. The on-board gasoline reformer faces a number of challenges that must be overcome as well. Reducing reformer start-up time and energy losses are key areas of improvement where R&D is and needs to be focused.

Safety and Storage Issues Need To Be Addressed

Issues related to hydrogen production and distribution, retail delivery, storage and vehicle safety must all be addressed and the unique safety challenges should be addressed through the development of data-based codes and standards. Hydrogen storage will be needed throughout the entire infrastructure spanning from the production site through the distribution system to the fueling station. Providing sufficient cost effective, bulk storage, which is a method to address supply-demand balance, will require new technology. Hydrogen storage on board vehicles is an area requiring new materials breakthroughs. Areas of focus include advanced materials for low-pressure storage, technologies to extend driving ranges and reducing storage costs.

Looking Ahead

As we move into this new century, the U.S. oil and natural gas industry will continue working with the automotive industry and government to keep improving our fuels and vehicles. Working together, we have made tremendous progress since the 1970s in reducing emissions and improving fuel economy while maintaining consumer satisfaction. Reduced auto emissions have contributed heavily to the dramatic reductions in overall emissions of major pollutants. Despite a 41 percent increase in energy consumption in that time period, ambient levels of carbon monoxide have been reduced by 28 percent, sulfur dioxide by 39 percent, volatile organic compounds by 42 percent, and particulate matter by 75 percent. We will accomplish a great deal more this decade under existing standards of the Clean Air Act as well as new national vehicle emission and fuel standards that come into effect in 2004 and 2006.

The auto and oil industries have made tremendous progress together over the years, introducing a range of improved vehicles and enabling fuels to reduce emissions, and increase fuel economy, and performance. We fully expect this trend to continue and strongly support R&D focused on achieving the full potential of advanced internal combustion engines, hybrids, and advanced fuels. We also recognize the long-term commitment required for R&D focused on the breakthroughs necessary to enable fuel cell vehicles and hydrogen fuel opportunities.

Moreover, whatever role government plays in fuel cell development, it should be a broad one. Government should encourage a multi-faceted approach. We believe that government's research role should be focused on pre-competitive, breakthrough research, leaving it to the private sector to build on this research and move the outcomes into the commercial development phase. The government should not prematurely focus on one approach while discouraging other approaches that may have high potential. Advanced technologies should compete on a level playing field with the American consumer ultimately making the choice of which technologies will be successful.

Our industry wants to work with government and others in the private sector to evaluate fuel cells and other advanced vehicle fuel systems from a well-to-wheels perspective. We believe that fuel cells may have an important role to play in the nation's transportation fuels future. We also believe that the fuel cell and hydrogen challenge should be viewed as a system. Each piece of the system, including the primary source of hydrogen, the production, distribution, retail delivery, and storage of hydrogen and the fuel cell vehicle itself, has challenges that must be overcome with innovative breakthroughs in order for the system to become competitive. We should take advantage of, and capture, the benefits of advanced gasoline and diesel technologies, including hybrid technology, in the near- and mid-term while the challenges of fuel cell and hydrogen technologies are being researched. The U.S. oil and natural gas industry is committed to playing a leading role in this important national effort.

UNIVERSITY OF MICHIGAN
COLLEGE OF ENGINEERING
July 5, 2003

The Honorable JOE BARTON
Chairman
Subcommittee on Energy and Air Quality
2125 Rayburn House Office Building
Washington, D.C. 20515

Dear CONGRESSMAN BARTON: Thank you for the opportunity to appear before the Subcommittee on Energy and Air Quality on May 20, 2003 to testify regarding the hydrogen energy economy.

Enclosed are my responses to questions from the Honorable Christopher Cox. The basic research initiative blueprint is also submitted in response to a request by the Committee during Question and Answers to provide a blueprint for a basic research initiative.

Sincerely,

JOHANNES SCHWANK
Professor of Chemical Engineering

RESPONSE TO QUESTIONS FROM CONGRESSMAN CHRISTOPHER COX

Question 1. If I wanted to start a commercial hydrogen fueling station, what regulatory obstacles might prevent me from opening it?

Question 2. Are hydrogen fuel cell vehicles allowed to drive through tunnels? What about trucks carrying compressed or liquid hydrogen cargo?

Question 3. Can we trust ordinary people to fuel their own cars at a hydrogen pump, or do we need specially-trained technicians?

Question 4. Is it safe to park a fuel cell vehicle inside a garage? Why or why not? What needs to change to make it safe?

Response: The four questions address issues that are related to regulation of hydrogen transport and dispensing as fuel for fuel cell vehicles. The regulation of the transportation of hydrogen is not my particular area of expertise. I believe that the definition of standards and regulations is best left to the federal and state agencies enforcing them and industries most affected by them.

I note that there are still many open questions regarding whether hydrogen should be *generated* centrally or on-site, and how to best *store* hydrogen (e.g. as compressed gas, liquid, or in solid-state storage materials). There are a number of possible alternatives for hydrogen generation, storage, and distribution that need to be researched and further developed before major decisions on infrastructure deployment can be made. Depending on the chosen hydrogen generation, storage, and distribution infrastructure, appropriate standards and regulations will then need to be developed. Therefore, it is essential that we not choose winning and losing technologies now. It is too early in the development process to assume that the best alternatives are to use liquid hydrogen centrally produced. Instead, we should focus our national efforts on exploring the vast array of alternatives.

Thus, a great deal of basic research is still needed to insure that hydrogen energy can be efficiently used in a safe cost effective manner. This is why there is a pressing need for a national hydrogen energy basic research initiative. One possible approach for initiating and carrying this out is attached.

A University-Based Hydrogen Energy Research Initiative

Tapping the Nation's Research Universities to Achieve the Hydrogen Economy

Johannes Schwank, Levi Thompson, Dennis Assanis, and James MacBain,
University of Michigan College of Engineering, Ann Arbor, Michigan

June 24, 2003

Introduction and Overview

During 2002, the six billion people of the world used 13 trillion watts (13 terawatts) of energy. The major portion of this energy came from fossil fuels. By 2050, an estimated 8-10 billion people in the world will require 30 to 50 terawatts of power to sustain their homes, industries, and transportation systems. Over the last decades, we have seen a clear trend showing a transition from carbon-rich fossil fuels such as coal and petroleum to fuels containing less carbon and more hydrogen, such as natural gas. One of the major drivers for this trend has been the need to reduce carbon dioxide emissions into the atmosphere. This trend will culminate in eliminating carbon altogether, and building an economy based on hydrogen as the primary energy carrier.

The world is on the threshold of entry into a hydrogen economy. To bring this transition about will require significant technical advances in new materials, processes, and infrastructure. It will also require a significant investment on the part of government and industry. The consensus in the industrial and academic sectors is that we must find economically and technically sound ways to produce, store, distribute, and utilize hydrogen. It is critical for the Nation's economy and its security that it be the global leader in developing the core technologies to accomplish this.

It is important that we develop a sound scientific and technical foundation, encompassing a wide spectrum of hydrogen-related fundamental and applied research issues. We must better understand the advantages and disadvantages of all our technology options before selecting specific technologies. The Nation's research university system is ideally suited to the task of establishing a sound scientific basis for developing hydrogen technology. Unfortunately, current federally sponsored research efforts are a patchwork at best. There is no coordinated federal research program in place that engages U.S. universities to address hydrogen energy issues. Although some universities receive federal support for research projects that address some aspects of hydrogen-based energy research, the scope and scale of the federal effort to tackle the important technical challenges is sorely inadequate. If we as a Nation are going to secure our technical leadership position in the world by leading the transition to a hydrogen economy, we must create a more comprehensive and coordinated program.

We propose that a Hydrogen Energy Research Initiative be established that effectively engages the intellectual capabilities of the Nation's universities. The magnitude of such a program should be on par with national science and technology initiatives like the Information Technology Research Initiative or the National Nanotechnology Initiative. The framework of such an initiative, its organization and research objectives, are described in the following sections.

The University-based Hydrogen Energy Research Initiative

Approach

We, at the University of Michigan, propose that a university-based Hydrogen Energy Research Initiative or HERI be established at either the National Science Foundation or the Department of Energy. In either case, basic research funds from all of the federal agencies promoting energy research should be used to supplement the program. Using a competitive peer-review process, a group of 8-10 university-based consortia, in partnership with industry and government, would be selected to undertake an integrated set of basic research and education projects focusing on the various components of hydrogen as an energy carrier. Each university center would execute basic research projects and develop undergraduate and graduate educational programs focusing on hydrogen-based energy technologies. In addition to scientific and engineering analyses of promising candidate systems, economic, social and environmental issues would be investigated. This will facilitate benchmarking of candidate systems and multidisciplinary synergy.

To facilitate the development and adoption of promising technologies, the HERI would provide supplemental "technology accelerator" seed funding to encourage technology development by businesses, in partnership with universities. States should be encouraged to augment technology accelerator programs with state-funded economic development programs that would further the development of small energy-focused businesses and facilitate their linkage to larger companies within the state.

Payoff

A university-based center of excellence program that broadly focuses on the Nation's energy research and education needs will provide significant leveraging of federal research dollars. Because it is located at the beginning of the research, development and engineering continuum, it avoids the risky practice of picking "winners and losers." Importantly, it facilitates technology transfer by encouraging industry partnerships to develop promising technologies.

Funding

Annual funding of at least of $11M per center would be necessary. An approximate breakdown would be: $8M for basic research and education, $2M for technology accelerator projects, and $1M (nominal state funding) for economic development facilitation. Each Center should receive federal funding for a 5-year period with an additional 5-year renewal based upon performance. Ideally, the HERI would support 8-10 such centers, requiring total federal funding of $80-100 million/yr.

HERI Center Activities and Operation

The HERI would provide an ideal platform to bring together academia, industry, and government to address hydrogen energy basic research issues. The participation of engineers and scientists from member companies and government agencies on specific research projects would be strongly encouraged. In brief, each university center would:

- Focus on precompetitive fundamental hydrogen energy research
- Educate and train students and industry practitioners about hydrogen-related technologies.
- Foster technology transfer and economic development by selecting projects based on technical merit and commercial potential.
- Carry out joint research projects in collaboration with industry and government partners.
- Facilitate technology transfer to industry partners.
- Provide a forum for engineers, scientists, and business leaders to share ideas and develop collaboration.

HERI Basic Research Program

Universities would carry out precompetitive fundamental research in areas that limit the use and adaptation of hydrogen energy technologies. Most projects would be done in partnership with industry. Hydrogen-based energy systems would be the primary focus of the research program. Research would be conducted in the general areas of:

- Hydrogen Generation
- Hydrogen Storage
- Hydrogen Distribution
- Hydrogen Utilization (stationary, mobile, micro)
- Business, Market and Economic Issues

Hydrogen is the ideal future energy and power storage/transport medium for the nation and world. It has high energy density, the ability to be converted to electrical, and thermal energy via highly efficient, non-polluting processes, and the potential of being produced from water, an abundant, renewable natural resource. The transition from the present hydrocarbon economy to a hydrogen economy is one of the great challenges of this century and will require significant advances in a number of technical and business areas. In 2002, the National Hydrogen Energy Roadmap Workshop, a meeting of more than 200 representatives from hydrogen energy industries, academia, environmental organizations, federal and state government agencies, and national laboratories, identified hydrogen production, delivery, storage, energy conversion, applications, and public education and outreach as the most important barriers and needs to be addressed in this quest.

Hydrogen Generation. In the near term (perhaps for the next 20 years), hydrogen will most likely be generated from natural gas or liquid fuels. To convert these fuels into hydrogen requires elaborate chemical processes carried out in a reactor system called a "fuel processor". Processing of hydrocarbon fuels inevitably leads to carbon dioxide as byproduct, in essence only shifting the point where carbon dioxide emission occurs without solving the environmental problem. Nevertheless, given the massive existing infrastructure for fossil fuels, we need to utilize this infrastructure to facilitate the gradual transition to a hydrogen economy. The large-scale, industrial production of hydrogen from natural gas or liquid fuels is a technically mature process, however this process does not properly scale for smaller-scale, distributed on-site hydrogen generation in gas stations or homes. To realize local hydrogen generation, new types of fuel processors with better catalysts need to be developed. Recent advances in the field of catalysis, leveraged by novel tools including combinatorial catalyst synthesis, high-throughput screening, and computational chemistry, promise to accelerate the discovery process.

An alternative to fossil fuels is the use of renewable sources such as biomass. The foremost difficulty in utilizing biomass is its sheer bulk. Transportation to a central processing facility is prohibitively expensive and limits its use. Finding ways to reduce the size of process equipment would permit its use in mobile systems that could convert biomass directly in the field to a liquid bio-fuel. Liquid fuel is easy to transport to a central facility where it can then be processed to generate hydrogen. Currently, we lack the scientific basis for efficient, small-scale biomass conversion to hydrogen.

Both biomass and fossil fuel-derived hydrogen causes carbon dioxide emissions into the atmosphere, unless we find efficient and economic methods for carbon sequestration. To avoid the carbon dioxide emission altogether, and free the Nation from the need to import oil, our ultimate goal has to be production of hydrogen from water, an abundant carbon-free source of hydrogen, relying on solar or nuclear energy to split water into hydrogen and oxygen. There are many existing methods to generate hydrogen from water, but at present, they are not economical on a large scale. There is tremendous opportunity for innovative basic research. For example, imagine the discovery of a new photocatalytic material that can efficiently split water and generate pure hydrogen, relying on "free" solar energy. The economic and strategic impact of such a discovery would be staggering! We have the finest academic research infrastructure in the world that can be engaged in this type of high risk/high reward research challenge.

Storage. Hydrogen storage is arguably the key to the commercialization of fuel cell powered automobiles and light trucks. While some progress has been made over the last decade, the present practical storage limits of approximately 5 wt% are nearly a factor of two lower than targets established by the automobile industry. Materials that appear to hold promise for achieving hydrogen storage capacities near 10 wt% include carbon nanotubes, graphite nanofibers and metal-organic framework materials. Exploiting the potential of these materials will require a fundamental understanding of the hydrogen storage mechanisms.

Fuel Cells. Most of the engineering challenges for fuel cells including the design of electrode assemblies, and fuel-oxidizer-water-waste flows have been met. The major challenges that remain, including durability, efficiency, and tolerance to impurities, can only be addressed by discovering and developing new and better performing materials. These challenges represent a significant opportunity for catalyst and materials research. This research would benefit from the use of surface science and computational chemistry methods. Specific hydrogen fuel cell research challenges include the discovery and development of better performing, low cost cathode catalysts to reduce the over-potential at practical operating currents, and membranes with higher proton conductivities, better mechanical strength and longer life that do not require high pressures to maintain hydration above 80°C. It is also important to develop anode catalysts that have significantly reduced Pt loadings and are more tolerant to impurities in the hydrogen gas.

Hydrogen Internal Combustion Engines. Hydrogen has great potential as an alternative fuel for internal combustion engines (ICE) operating either in the conventional, spark-ignition (SI) or compression ignition modes. Published results have shown that hydrogen burning ICEs can accomplish thermal efficiencies in the range of 45-50% with virtually no emissions other than NO_X. With its extreme lean flammability and low ignition energy, H_2 allows ultra lean combustion to be realized in SI engines at the low temperatures needed to minimize NO_X production. In addition, engine load can be controlled by changing the charge quality thus removing throttling and significantly improving the part load efficiency. The very high octane value of hydrogen can be used to realize a higher compression ratio for high thermal efficiency without knocking. However, hydrogen's combustion properties also pose some significant challenges for utilization in ICEs. In particular, due to its low ignition temperature, hydrogen can lead to pre-ignition and backflash, especially as a lean fuel/air mixture approaches stoichiometric levels, thus limiting the output from hydrogen burning ICEs. The power density of a hydrogen ICE is also limited by volumetric efficiency considerations. Fundamental research is needed to demonstrate the improvement in thermal efficiency and reduction in pollutant formation as a result of hydrogen combustion in ICEs, and to address the associated scientific and engineering challenges through well coordinated experimental and modeling efforts. New technologies such as hydrogen direct injection, supercharging and hybridization also need to be investigated. In parallel, the potential for utilizing hydrogen-augmented hydrocarbon fuels in compression ignition ICEs, and also hydrogen's role in reducing cold start emissions and enhancing the performance of after-treatment devices should be investigated.

Center Educational Program on Hydrogen Energy Technologies

Each center would bring together faculty from multiple disciplines, including chemical engineering, materials science, mechanical engineering, chemistry, natural resources, business, and public policy. These disciplines would be the basis for a rich crosscutting educational program addressing energy-related issues. In addition, the joint research projects with industry will make them an ideal tool for exploring innovative approaches to engineering and business education, including electives that cut across traditional disciplinary boundaries. The ability to mix students with different backgrounds in team-oriented research is critical in educating future engineers, scientists, and business managers in the fast-breaking and rapidly changing area of alternative energy.

Further, in both undergraduate and graduate programs, multi-university multidisciplinary distance learning and virtual-laboratory experiences should be employed in the development of special course sequences addressing alternative energy systems.

Industry and Government Outreach and Collaboration

Strong industry and government involvement in the Centers is critical in terms of research relevancy and to facilitate technology transfer. Two key objectives of each center's industrial and government program will be a), to facilitate the timely transfer of promising research developments to industry and government and b), to support an active collaboration in each Center's research and education programs.

Industry membership in the center implies an active working partnership in the research and development of the key technologies and major research issues that will enable the development of alternative energy technologies. In a typical center, members would be entitled to the following benefits:

- Early awareness of new developments in alternative energy research
- Preferential access to center-generated intellectual property
- Facilitated access to students
- Web access to the Center's alternative energy information clearinghouse
- Priority access to Center research facilities and personnel
- Potential membership on the Center Executive Committee
- Preferential access to distance learning and educational programs
- Participation in a neutral forum for researchers, designers, builders, suppliers, and end-users
- Significant leveraging of company R&D through federally funded research programs
- Participation is topical technology workshops, seminars, and conferences.

Technology Transfer. When at all possible, Center research projects would be carried out with industry in order to accelerate the development and broad dissemination of challenging, high-risk alternative energy technologies that offer the potential for significant commercial payoffs and widespread benefits for the Nation.

Where state support of research projects is available, "technology accelerator" grants could also be awarded to university-industry teams for the purpose of accelerating the development and implementation of emerging or enabling technologies within the given state. Thus, they would not only further the research but would promote economic development as well.

To facilitate the transfer of center technology to industry and government application, all center research projects will be strongly encouraged to organize on a "Quad" concept. Essentially, this means that any individual research project undertaken by the Center at any of the participating universities shall require the active participation of four entities: faculty, students (graduate or undergraduate), industry engineers or scientists, and government engineers or scientists as depicted in Figure 1. The basic rationale for using the Quad is that technology is much more effectively transferred if all parties are involved in its development from inception to implementation.

Conclusion

A university-based Hydrogen Energy Research Initiative that broadly focuses on the Nation's energy research and education needs will provide a significant intellectual impetus and capital to the country's pressing energy needs. It will also significantly leverage federal research dollars. Basic research carried out in research universities provides the foundation for the research, development, and commercialization continuum. Importantly, it facilitates technology transfer by moving new discoveries and innovations from the laboratory to the market place, and encouraging industry partnerships to develop promising technologies. For our Nation, it is of critical strategic and economic importance that the academic, industrial, and government sector work together to assure that we lay a strong research foundation, permitting us to select the best pathways and technologies leading to our hydrogen-based energy future.

NATIONAL FUEL RESEARCH CENTER
UNIVERSITY OF CALIFORNIA, IRVINE
July 7, 2003

The Honorable JOE BARTON
Chairman
Subcommittee on Energy and Air Quality
Committee on Energy and Commerce
U.S. House of Representatives
Washington D.C. 20515-6115

DEAR REPRESENTATIVE BARTON: In response to your letter dated June 16, 2003, attached please find my response to the questions presented.

Please advise me should you desire additional assistance.

Sincerely,

SCOTT SAMUELSEN, *Director*
Professor of Mechanical, Aerospace, and Environmental Engineering

Question 1: If one wanted to start a commercial hydrogen fueling station, what regulatory obstacles might prevent one from opening it?

Response: While hydrogen filling stations have been established and are operating,[1] use is restricted and not available to the general public. Commercial stations will emerge with conditional use this calendar year. The National Fuel Cell Research Center (NFCRC), for example, is under contract from the South Coast Air Quality Management District (AQMD) to establish two such stations.

The regulatory obstacles that dissuade opening a commercial station are (1) the lack of codes and standards for public use of hydrogen dispensing, and (2) the lack of national coordination to assure standardization across the country of applicable codes. There are approximately 44,000 code jurisdictions within the United States. Today, local regulatory bodies, unfamiliar with a product or technology, request substantial and unique documentation which substantially delays approvals and affects competitive positions in the market.

As a result, there is a strong need for nationally standardized codes and standards for public use of hydrogen dispensing that are coordinated on an international basis. The U.S. Department of Energy (DOE) has contracted with the National Hydrogen Association (NHA) to work on this process with its members from industry and government. Hydrogen has been safely generated, distributed, and utilized in industrial applications for decades. The challenge now is to establish codes and standards designed for public use of hydrogen.

The NHA Hydrogen Codes and Standards Coordinating Committee was established to coordinate the diverse activities by the large number of organizations involved in developing and adopting codes for hydrogen technologies. In addition, The International Standards Organization Technical Committee 197 has been working to adopt international standards for hydrogen technologies. Ongoing efforts to establish standards are focusing on establishing safe handling practices, facilitating standard interfaces, eliminating barriers to international trade, and developing quality criteria and testing methods.

The NFCRC supports these efforts but encourages Congress to establish a path that will assure hydrogen codes and standards for public use are deployed and standardized as a national initiative.

Question 2: Are hydrogen fuel cell vehicles allowed to drive through tunnels?

Response: The NFCRC is not aware of travel restrictions for driving hydrogen-fueled fuel cell vehicles through tunnels at the current time. The reasons are two-fold. There are neither restrictions nor permits for such travel due to the novelty of hydrogen-fueled vehicles. A similar question is raised with regard to parking hydrogen fuel vehicles in public structures or in residential garages. Such considerations are integral to the development of codes and standards for the public use of

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[1] For Example, (1) City of Las Vegas Public Works; (2) California Fuel Cell Partnership, Sacramento, California; (3) Sunline Transit District, Palm Springs, California; (4) Toyota Motor Sales, Torrance, California; (5) National Fuel Cell Research Center, University of California, Irvine, California.

hydrogen, in this case the "utilization" of hydrogen versus the "dispensing" of hydrogen raised by Question 1.

We expect the codes and regulations for hydrogen-fueled vehicles in tunnels to mirror the codes and regulations established for compressed natural gas (CNG) vehicles.

Question 3: What about trucks carrying compressed or liquid hydrogen cargo?

Response: There are restrictions on the transportation of hydrogen that vary from state to state. The Department of Transportation (DOT) standards are in place for transporting various gases and chemicals and can be superceded by local agencies such as the California Highway Patrol at their discretion.

Question 4: Can we trust ordinary people to fuel their own car at a hydrogen pump, or do we need specially trained technicians?

Response: Today, ordinary people with proper training refuel their vehicles with Compressed Natural Gas (CNG). The procedure is expected to be similar for hydrogen refueling. In the early stages, steps must be taken to educate the public on the procedures for compressed-gas refueling. While this is accomplished today for CNG refueling, CNG vehicles (with few exceptions) are operated within fleets and the training is thereby facilitated. As hydrogen-fueled vehicles become ubiquitous in society, special procedures will be required to assure public safety. For example, in licensing a hydrogen-fueled vehicle, the owner may be required to complete refueling training. In addition, professional staff may be necessary at hydrogen refueling stations for the first decade in order to assure a robust public education process.

Question 5: Is it safe to park a fuel cell vehicle inside a garage?

Response: With reasonable safety measures, such as adequate roof top ventilation, yes. However, codes and standards must be established to specify the ventilation required and assure that building codes accommodate the appropriate specifications.

Question 6: Why or why not? What needs to change to make it safe?

Response: Hydrogen has a long history of safe usage in the chemical and aerospace industries. As with any fuel (e.g., gasoline, natural gas, propane), an understanding of the properties, proper safety precautions and established rules are key to its successful safety track record.

By their nature, all fuels have some degree of danger associated with them. The safe use of any fuel focuses on preventing situations where the four combustion factors—ignition source (spark or heat), oxidant (air) fuel, and confinement are present.

Hydrogen has properties that make it safer to handle and use in many regards than the fuels commonly used today. For example, hydrogen is non-toxic. In addition, because hydrogen is much lighter than air, it dissipates rapidly should it be released, allowing for relatively rapid dispersal of the fuel in case of a leak. The properties of hydrogen that do require additional engineering and controls include its wide range of flammable concentrations in air and lower ignition energy than gasoline or natural gas, which means hydrogen can ignite more easily in the absence of appropriate ventilation. As a result, adequate ventilation and leak detection are important elements in the design of safe hydrogen vehicles and vehicle storage facilities. The unusually high fuel pressures associated with the early deployment of hydrogen-fueled vehicles will require aggressive codes and standards for the fuel tanks to assure controlled rupture in the case of an unscheduled penetration. Other commonly practiced safety issues, such as those associated with fuels used today would also apply, such as avoiding ignition sources.

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