THE HYDROGEN ECONOMY: IS IT ATTAINABLE? WHEN?

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND RESOURCES

OF THE

COMMITTEE ON GOVERNMENT REFORM

HOUSE OF REPRESENTATIVES

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THE HYDROGEN ECONOMY: IS IT ATTAINABLE? WHEN?

WEDNESDAY, JULY 27, 2005

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENERGY AND RESOURCES,
COMMITTEE ON GOVERNMENT REFORM,
Washington, DC.

The subcommittee met, pursuant to notice, at 1:10 p.m., in room 2203, Rayburn House Office Building, Hon. Darrell E. Issa (chairman of the subcommittee) presiding.

Present: Representatives Issa and Kucinich.

Staff present: Larry Brady, staff director; Lori Gavaghan, legislative clerk; Dave Solan, Steve Cima, and Chase Huntley, professional staff members; Richard Butcher, minority professional staff member; and Cecelia Morton, minority office manager.

Mr. ISSA. Ladies and gentlemen, I appreciate your patience. Please remain standing, you will feel more comfortable. All those who are testifying or who may advise those testifying, please raise your right hands. It is our custom to have all witnesses sworn.

[Witnesses sworn.]

Mr. ISSA. From everyone who is here in attendance today, a quorum is present. We do expect to have Members in and out. I apologize. The importance of this hearing caused us not to cancel it in spite of the fact that there are markups in virtually every committee of the House trying to get prepared for getaway day which should be Thursday, Friday, Saturday or Sunday.

But this is an important hearing and I appreciate your very large attendance.

Today we will discuss our country's progress toward a hydrogen economy. Are our goals attainable and when?

The United States is increasingly dependent on imported energy sources to power the country's vehicles and sustain the Nation's growing economy.

But our Nation's increasing reliance on overseas oil imports acts as a drag on our economy. This year high oil prices will likely account for more than a third of our annual trade deficit.

Furthermore, all too often the foreign sources the United States depends on for fuels are located in insecure regions of the world and, in some cases, are under the control of nations which are hostile to the United States.

At this time when national security and environmental concerns, including climate change, are at the forefront of our policy discussions, government and industries around the world are looking at hydrogen as a major energy carrier of the future.

Hydrogen holds the potential to be the backbone of a safe, environmentally friendly and sustainable energy system for our Nation's future.

However, clean, efficient and cost effective hydrogen production is a significant challenge.

As a fuel, hydrogen does not exist in a readily usable form in nature like oil and coal. Rather it more closely resembles electricity, an energy carrier that must be generated from another fuel source.

Moreover, commercially viable technologies to store and efficiently convert hydrogen into energy appear to be years away.

In 2003, the President announced an ambitious effort to transition the country to an economy powered not by hydrocarbons, but by hydrogen. This hearing will assess how and when this goal might be attained.

In other words, is a hydrogen economy attainable and if so, when?

Our first panel will examine the status of the Federal initiatives aimed at realizing the President's vision, including the extent of Federal support for leading State initiatives.

We are pleased to welcome three committed public servants: the Honorable Douglas Faulkner, Acting Assistant Secretary for Energy Efficiency and Renewable Energy at the Department of Energy; the Honorable Richard Russell, Associate Director for Technology at the White House Office of Science and Technology Policy; and Dr. Alan Lloyd, Agency Secretary of the California EPA and someone who I had a personal opportunity to begin the conversation with. I appreciate your appearing twice.

Our second panel will offer their insights on these Federal initiatives, meaning whatever you say we are going to have the private sector address on the second panel.

It will include Dr. Lawrence Burns, vice president of Research and Development at General Motors Corp.; Mr. Dennis Campbell, president and chief executive officer, Ballard Power Systems; Dr. Mujid Kazimi, member of the National Academies' Committee on hydrogen production and use; and Dr. Dan Sperling, director of the Institute of Transportation Studies at the University of California, Davis.

I look forward to hearing your testimony. When the ranking member arrives, we will pause for her statement.

Mr. Faulkner, you are first.

[The prepared statement of Hon. Darrell E. Issa follows:]

COMMITTEE ON GOVERNMENT REFORM
SUBCOMMITTEE ON ENERGY AND RESOURCES

OPENING STATEMENT OF
CHAIRMAN DARRELL ISSA
"The Hydrogen Economy: Is it Attainable? When?"
JULY 27, 2005

The United States is increasingly dependent on imported energy sources to power the country's vehicles and sustain the nation's growing economy.

But, our nation's increasing reliance on overseas oil imports acts as a drag on our economy. This year, high oil prices will likely account for more than 1/3rd of our annual trade deficit.

Furthermore, all too often the foreign sources on which the U.S. depends for these fuels are located in insecure regions of the world and, in some cases, are under the control of nations which are hostile to the U.S.

At a time when national security and environmental concerns—including climate change—are at the forefront of our policy discussions, governments and industries around the world are looking at hydrogen as the major energy carrier for the future.

Hydrogen holds the potential to be the backbone of a safe, environmentally friendly, and sustainable energy system for the nation's future.

However, clean, efficient, and cost-effective hydrogen production is a significant challenge.

As a fuel, hydrogen does not exist in a readily usable form in nature like oil or coal. Rather, it more closely resembles electricity—an energy carrier that must be generated from another fuel source.

Moreover, commercially viable technologies to store and efficiently convert hydrogen into energy appear to be years away.

In 2003, the President announced an ambitious effort to transition the country to an economy powered not by hydrocarbons, but by hydrogen. This hearing will assess how and when this goal might be attained—in other words, is a hydrogen economy attainable, and, if so, when?

We look forward to hearing from our distinguished witnesses. Our first panel will examine the status of the federal initiatives aimed at realizing the President's vision, including the extent of federal support for leading state initiatives. We are pleased to welcome three committed public servants:

- Douglas L. Faulkner, Acting Assistant Secretary for Energy Efficiency and Renewable Energy at the Department of Energy;
- Richard Russell, Associate Director for technology at the White House Office of Science and Technology Policy; and
- Dr. Alan Lloyd, Secretary of the California Environmental Protection Agency.

Our second panel will offer their insights on these federal initiatives from a variety of perspectives, including the National Academies, private companies, and the academic community. We are pleased to welcome:

- Lawrence Burns, Vice President of Research and Development at General Motors Corporation;
- Dennis Campbell, President and Chief Executive Officer of Ballard Power Systems;
- Mujid S. Kazimi, Member of the National Academies' Committee on hydrogen production and use; and
- Dan Sperling, Director of the Institute of Transportation Studies at the University of California, Davis.

I look forward to the testimony of these distinguished witnesses.

STATEMENTS OF DOUGLAS L. FAULKNER, ACTING ASSISTANT SECRETARY FOR ENERGY EFFICIENCY AND RENEWABLE ENERGY, U.S. DEPARTMENT OF ENERGY; RICHARD M. RUSSELL, ASSOCIATE DIRECTOR FOR TECHNOLOGY, OFFICE OF SCIENCE AND TECHNOLOGY POLICY; AND ALAN LLOYD, AGENCY SECRETARY, CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

STATEMENT OF DOUGLAS L. FAULKNER

Mr. FAULKNER. Mr. Chairman and members of the committee, I appreciate the opportunity to testify on the Department of Energy's hydrogen program. Today I will cover our plans, our progress and our partners focusing on State initiatives, demonstration projects and what we believe must be accomplished.

Since President Bush launched the hydrogen fuel initiative over 2 years ago, we have implemented the valuable feedback from the National Academy of Sciences and have already seen results.

In fact, as we speak the Academy is completing its biennial review of the program. We developed the Hydrogen Posture Plan with strategies, milestones to enable a 2015 industry commercialization decision. We are now implementing our plans and making tangible progress.

The Department competitively selected over $510 million in Federal funding, subject to appropriations, for projects to address critical challenges. DOE's Office of Science announced 70 new projects on topics such as new materials and catalyst design at the nano scale.

We established the National Hydrogen Storage Project, including three centers of excellence to focus on hydrogen storage, a critical technology for the hydrogen economy.

Sixty-five projects were initiated on hydrogen production and delivery and the results are already promising. We believe we can meet our goal of $2 to $3 per gallon of gasoline equivalent which is independent of production pathway. Our ultimate goal is carbon-neutral hydrogen production that emphasizes resource diversity.

To address fuel cell costs and durability, we have a new $75 million solicitation of complement current work. Results are already being achieved here, too.

As highlighted by Secretary Bodman in earlier testimony, the high volume cost of automotive fuel cells was reduced from $275 to $200 per kilowatt. Through new strategies for fabricating electrodes and improving durability, we believe our targets are achievable.

As you know see, the program is focused on research, aligned with the academy's recommendation to shift away from some development areas toward exploratory work. But there is a value for a few selective demonstration projects.

We must keep sight of our ultimate goal to transfer research to the real world. We have complemented our research efforts with a learning demonstration activity. This 50–50 cost share activity brings auto and energy companies together to validate vehicle infrastructure technologies.

These are pre-commercial demonstrations and serve a specific purpose at this early stage, to gather technical data from real

world operations and help refocus our research efforts and validate progress toward our milestones. In May, President Bush participated in the refueling of a GM hydrogen vehicle at D.C.'s Benning Road Shell Station, which is involved in our learning demonstration effort.

The department is working with partners on all fronts to address the challenges to a hydrogen economy. Under the Freedom Car and Fuel Partnership, the Department of Energy is collaborating with the U.S. Council for Automotive Research and major automotive and energy companies. We conduct research on safety codes and standards working with the Department of Transportation and globally through the International Partnership for a Hydrogen Economy.

We are working with the Department of Commerce and other Federal agencies to create an R&D road map for manufacturing technologies. This effort will help attract new business, new investment, create new high technology jobs and create a competitive U.S. supply base.

We are also working with State governments to leverage resources, coordinate efforts and reduce duplication. Hydrogen initiatives exist now in more than 10 States. For instance, since we participate in the California Fuel Cell Partnership and the California Hydrogen Highway Network, the working group sharing information and technology expertise.

Last year the Hydrogen 101 education workshop was offered to interested State and local governments. States can also serve a role to education target audiences including safety and code officials in local communities and to catalyze the research community to focus on R&D needs for a hydrogen economy. The realization of the national hydrogen economy will eventually require the active and sustained participation of State leaders at many levels.

Mr. Chairman, the DOE hydrogen program is committed to a balanced portfolio which integrates basic and applied research, engineering development and learning demonstrations. We anticipate staying in close touch with State and local governments as our Federal partnership matures.

This completes my prepared statement. I would be happy to answer any questions.

[The prepared statement of Mr. Faulkner follows:]

Statement of Douglas L. Faulkner

Acting Assistant Secretary for Energy Efficiency and Renewable Energy

Before the

Subcommittee on Energy and Resources

Committee on Government Reform

U.S. House of Representatives

July 27, 2005

Mr. Chairman and Members of the Subcommittee, I appreciate the opportunity to testify on the Department of Energy's (DOE or Department) Hydrogen Program. Today, I will provide an overview of the program, summarize progress in implementing the recommendations of the National Academies' hydrogen report, discuss support for state initiatives and demonstration projects, as well as provide a status of the Hydrogen Program's accomplishments and plans.

Over two years ago, in his 2003 State of the Union address, President Bush announced the Hydrogen Fuel Initiative to reverse America's growing dependence on foreign oil by developing the hydrogen technologies needed for commercially-viable fuel cells – a way to power cars, trucks, homes, and businesses that could also significantly reduce criteria pollutants and greenhouse gas emissions. Since the launch of the five-year, $1.2-billion research initiative, we have had many accomplishments on the path to taking hydrogen and fuel cell technologies from the laboratory to the showroom in 2020, following an industry commercialization decision in 2015.

Our Hydrogen Program emphasizes the research and development (R&D) activities necessary to achieve the President's vision of a hydrogen economy and to address foreign oil dependence and greenhouse gas emissions. Our R&D efforts address the critical path barriers to the hydrogen economy. As an extension of these research activities, we have also established a 50-50 cost-shared partnership with industry to create a "learning" demonstration. These demonstration projects ensure that the automotive and energy industries will work together to integrate vehicle and infrastructure technologies prior to market introduction.

Drivers for Hydrogen Research: Energy and Environment

As a Nation, we must work to ensure that we have access to energy that does not require us to compromise our economic security or our environment. Hydrogen offers the opportunity to end petroleum dependence and virtually eliminate transportation-related criteria and greenhouse gas emissions by addressing the root causes of these issues. Imported petroleum already supplies more than 55 percent of U.S. domestic needs and

those imports are projected to increase to more than 68 percent by 2025 with business-as-usual. Transportation accounts for two-thirds of the oil use in the United States and vehicles contribute to the Nation's air quality problems and greenhouse gas emissions because they release criteria pollutants and carbon dioxide.

At the G8 Summit earlier this month, President Bush reiterated his policy of promoting technological innovation, like the development of hydrogen and fuel cell technologies, to address climate change, reduce air pollution and improve energy security in the United States and throughout the world. The Department's R&D in high-efficiency vehicle technologies, such as gasoline hybrid-electric vehicles, will help improve energy efficiency and reduce the growth of petroleum consumption in the nearer term. Under DOE's FreedomCAR Program, the President's FY 2006 budget request is $100.4 million. This funding will make hybrid-vehicle components, like batteries, power electronics, electric motors and advanced materials, more affordable. But, in the longer term, higher efficiency alone will not reduce our petroleum consumption; we ultimately need a substitute to replace petroleum. Hydrogen and fuel cells, when combined, have the potential to provide domestically-based, virtually carbon- and pollution-free power for transportation.

Hydrogen can be produced from diverse domestic energy resources, which include fossil fuels, nuclear energy, biomass, solar, wind and other renewables. We have planned and are executing a balanced research portfolio for developing hydrogen production and delivery technologies. Hydrogen from coal will be produced directly by gasification—not coal-based electricity. For hydrogen from coal to be viable, research in carbon capture and sequestration technologies must also be successful. The ultimate outcome we are seeking is hydrogen from carbon-neutral fossil, nuclear and renewable energy resources.

In the transition to the hydrogen economy, the Department recognizes that hydrogen will be produced by technologies that do not require a large, up-front investment in hydrogen delivery infrastructure. Instead, hydrogen can be produced at the refueling station by reforming natural gas and renewable fuels like ethanol utilizing existing delivery infrastructure. A fuel cell vehicle running on hydrogen produced from natural gas would produce 25 percent less net carbon emissions than a gasoline hybrid electric vehicle and 50 percent less than conventional internal combustion engine vehicles on a well-to-wheels basis. However, natural gas is not a long-term strategy because of concerns of limited supply and the demands of other sectors. As vehicle market penetration increases and research targets for the diverse hydrogen production and delivery technologies are met, these will help establish the business case for industry investment in large-scale hydrogen production and delivery infrastructure.

Major Challenges to the Hydrogen Economy

The President's FY 2006 request to Congress for the Hydrogen Fuel Initiative is $259.5 million. This funding is necessary to conduct the research to overcome the barriers to the hydrogen economy:

- The technology must be developed to store enough hydrogen on-board a vehicle to enable greater than 300-mile driving range without reducing cargo or passenger space.

- The high-volume cost of the fuel cell system must be reduced by a factor of seven in order to be competitive with today's internal combustion engines, and durability needs to be improved by a factor of five.

- The cost of producing hydrogen must be reduced to be competitive with the cost of gasoline. Hydrogen from natural gas reforming is currently about two times as costly as gasoline (untaxed) and hydrogen from other sources (renewables, nuclear energy and coal combined with sequestration) is even more costly.

- Improved materials and system designs must be developed to ensure the safe use of hydrogen. Codes and standards need to be developed to enable implementation of hydrogen technologies, and international standards are needed to eliminate trade barriers.

- Educational materials must be developed and available for key target audiences (e.g. first responders, etc.) to understand hydrogen and fuel cell technologies and their uses.

Progress and Accomplishments

Mr. Chairman, the Department has made significant progress in planning and setting the stage to achieve the research breakthroughs necessary for a future hydrogen economy. The Department has competitively selected over $510 million in projects to address critical challenges such as hydrogen storage, fuel cell cost and durability, and hydrogen production and delivery cost. In addition, we have established a national "learning" demonstration and new projects in safety, codes and standards, and education. All of the multi-year projects discussed below were competitively selected and are subject to congressional appropriations. The continuum of research, from basic science to technology demonstration, will be closely coordinated.

- In May 2005, 70 new projects were selected at $64 million over three years to focus on fundamental science and to enable revolutionary breakthroughs in hydrogen production, storage and fuel cells. Topics of this basic research include novel materials for hydrogen storage, membranes for hydrogen separation and purification, designs of catalysts at the nanoscale, solar hydrogen production, and bio-inspired materials and processes.

- Three Centers of Excellence and 15 independent projects were initiated in Hydrogen Storage at $150 million over five years to develop the most promising low-pressure storage approaches. The Centers include 20 universities, 9 federal laboratories and eight industry partners, representing a concerted, multi-disciplinary effort to address on-board vehicular hydrogen storage.

- To address fuel cell cost and durability, five new projects were initiated at $13 million over three years. A $17.5 million solicitation is currently open to research new membrane materials in fuel cells. And, a new $75 million solicitation will be released this fall to address cost and durability of fuel cell systems.

- A total of 65 projects were awarded for applied research in hydrogen production and delivery, funded at $107 million over four years. These include hydrogen production from renewables, distributed natural gas, coal and nuclear energy.

- A national vehicle and infrastructure "learning demonstration" project, a six-year effort with $170 million in DOE funding, was launched to take research from the laboratory to the real world, critically measuring progress and providing feedback to our R&D efforts.

- Approximately $7 million over four years for hydrogen education development was awarded to serve the needs of multiple target audiences, including state and local government officials, safety and code officials and local communities where hydrogen demonstrations are located.

With these new competitively selected awards, the best scientists and engineers from around the Nation are actively engaged. The stage is now set for results.

Our ongoing research has already led to important technical progress.

- As highlighted by Secretary Bodman in earlier Congressional testimony, the high-volume cost of automotive fuel cells was reduced from $275 per kilowatt to $200 per kilowatt in two years. This cost reduction was the result of increased power density; advancements in membrane materials; reductions in both membrane material cost as well as amount of membrane material required in the fuel cell; enhancement of specific activity of platinum catalysts; and innovative processes for depositing platinum and reducing the overall amount of catalysts.

- In hydrogen production, we have demonstrated our ability to produce hydrogen at a cost of $3.60 per gallon of gasoline equivalent at an integrated fueling station that generates both electricity and hydrogen. This is down from about $5.00 per gallon of gasoline equivalent prior to the Initiative.

Implementation of National Academies' Recommendations

We have implemented the valuable feedback from the National Academy of Sciences (NAS) review in March 2004 and are already seeing results. The NAS called for us "to improve integration and balance of activities" within the relevant DOE Offices (which include Energy Efficiency and Renewable Energy; Fossil Energy; Nuclear Energy, Science and Technology; and Science). We have done this by developing and publishing an integrated research, development and demonstration plan, called the "Hydrogen

Posture Plan," which covers all Department hydrogen activities. The Plan identifies the major milestones which need to be achieved to enable industry to make a 2015 commercialization decision. Each of the four offices has, in turn, developed a detailed research plan which outlines how the high-level milestones will be supported. Lower-level, time-phased, performance-based milestones form the basis for measuring research progress.

In response to another National Academies' recommendation, we established a systems analysis activity to examine the impact of different components or subsystems of hydrogen technology on the complete system, as well as establish the time frames needed for transition to a hydrogen economy. "Well-to-wheels" analyses assessing the energy, economic and environmental impacts of various hydrogen production and delivery pathways, as well as other systems analysis activities, will be valuable in technology decision-making and planning for a transition to the hydrogen economy.

The Hydrogen Program has increased emphasis on exploratory research in response to the NAS recommendation that "there should be a shift ... away from some development areas towards exploratory work" and that "the probability of success [will be] greatly increased by partnering with a broader range of academic and industrial organizations." In accordance with this recommendation, we have moved away from subsystem hardware development, such as fuel cell stack systems and conventional high-pressure storage tanks, to put greater emphasis on materials research.

Starting in FY 2005, DOE's Office of Science has been included in the Hydrogen Fuel Initiative in order to focus basic research on overcoming key technology hurdles in hydrogen production, storage and conversion. The Office of Science-funded research seeks fundamental understanding in areas such as novel materials for hydrogen storage with an emphasis on nanoscale structures and new storage concepts, non-precious-metal catalysts, membranes for fuel cells and hydrogen separation, multifunctional nanoscale structures, photocatalytic (including biological and bio-inspired approaches) and photoelectrochemical hydrogen production, and modeling and analytical tools. The three Centers of Excellence established through the Department's "Grand Challenge" solicitation are utilizing recent progress in materials discovery and technology which allows hydrogen to be stored at low pressures and modest temperatures. Rather than "stand alone" test tube research, we have an integrated effort to address basic, applied, and engineering sciences to develop materials and systems for storing hydrogen.

Through the hydrogen production solicitations, we have increased emphasis on long-term research. Last October, DOE announced industry and university grants of $25 million over three years, contingent upon appropriations, for solar-driven photoelectrochemical, thermochemical and photobiological technology. The NAS also recommended changes in other hydrogen production technology areas and advised DOE to "increase development of breakthrough approaches for small-scale reformers [,] ...research novel renewable liquid distributed reforming [and]...emphasize electrolyzer development." Our transition strategy emphasizes small-scale reformers and electrolyzers for refueling stations and distributed electricity generation sites. Through our solicitation, we have

added new projects totaling $30 million over 3 years, contingent upon appropriations, in these areas. We have worked with our energy industry partners to develop technology roadmaps that emphasize distributed technologies.

Collaboration through Partnerships

We are working with partners on all fronts to address the challenges to a hydrogen economy. Under the FreedomCAR and Fuel Partnership, DOE is collaborating with the U.S. Council for Automotive Research (DaimlerChrysler, Ford and General Motors) and five major energy companies (BP, Chevron, ConocoPhillips, ExxonMobil and Shell) to help identify and evaluate technologies that will meet customer requirements and establish the business case. Technical teams of research managers from the automotive and energy industries and DOE are meeting regularly to establish and update technology roadmaps in each technology area.

An Interagency Hydrogen R&D Task Force has been established by the White House Office of Science and Technology Policy (OSTP) to leverage resources and coordinate interrelated and complementary research across the entire Federal Government. This year, the Task Force initiated a plan to coordinate a number of key research activities among the eight major agencies that fund hydrogen and fuel cell research. Coordination topics include novel materials for fuel cells and hydrogen storage, inexpensive and durable catalysts, hydrogen production from alternative sources, stationary fuel cells, and fuel-cell vehicle demonstrations. The Task Force has launched a website, Hydrogen.gov, and in the coming year plans to sponsor an expert panel on contributions that nanoscale research can make to realizing a hydrogen economy.

Last year, we announced the establishment of the International Partnership for the Hydrogen Economy (IPHE). The IPHE, which now includes 16 nations and the European Commission, establishes world-wide collaboration on hydrogen technology. The members have agreed to work cooperatively toward a unifying goal: practical, affordable, competitively-priced hydrogen vehicles and refueling by 2020. Projects involving collaboration between different countries are being proposed and reviewed for selection.

State Initiatives and Demonstration Projects

The Department supports the growing number of state hydrogen initiatives by providing accurate and objective information about hydrogen and fuel cell technologies. Hydrogen initiatives exist in more than ten states, including California. The Department is a member of the California Fuel Cell Partnership and has participated on planning committees for the California Hydrogen Highway Network. Today, 21 full members and ten associate members representing eight automakers, four fuel providers, the supplier industry, as well as state and Federal Government agencies (including DOE, DOT, and EPA), are working together through the Partnership to share their experiences operating first-of-their-kind research vehicles throughout California. The objective of the new

Hydrogen Highway Network initiative, championed by Governor Schwarzenegger, is to ensure that hydrogen fuel availability will match fuel cell vehicle demand.

As mentioned earlier, the Department's partnership with the automotive and energy industries to conduct a national "learning" demonstration project will expand the Program's research while leveraging industry investments in hydrogen and fuel cell technologies; subject to appropriations, the first phase of the project will total over $350 million, with more than 50 percent coming from industry. The project includes four automotive and energy teams made up of General Motors and Shell; Ford and BP; DaimlerChrysler and BP; and Chevron and Hyundai-Kia.

The goals of the project are:

- to obtain detailed component and performance data to guide the Department's hydrogen and fuel cell research, and
- to validate industry's progress toward meeting the milestones leading up to the 2015 commercialization decision.

Three major milestones for 2009, when phase one ends, are: 2,000-hours fuel cell durability; 250-mile vehicle range; and $3.00 per gallon gasoline equivalent hydrogen fuel.

While hydrogen fuel infrastructure and fuel cell vehicle technologies are not ready for widespread deployment or commercialization, DOE believes there is tremendous benefit in energy and auto companies working together before the market introduction phase to ensure that there is seamless integration. Transitioning to a hydrogen-based infrastructure from today's petroleum infrastructure will require coordination between stakeholders. For example, standards for hydrogen purity must be addressed before commercialization can happen. Fuel cell manufacturers would like the purest hydrogen available to ensure the best performance and longest durability; however, it will not be cost-effective for energy suppliers to produce and deliver perfectly pure, laboratory-grade hydrogen. Therefore, some compromise must occur and the demonstration program will provide the data necessary to facilitate development of hydrogen fuel quality standards prior to commercialization and infrastructure investment.

Toward the Hydrogen Future

DOE is looking to the future as well. Just as we have already made progress, we plan to have significant progress next year. The progress will be tracked using performance-based technical and cost milestones that provide clear and quantifiable measures. We will report this progress annually to Congress and to the Office of Management and Budget.

For our critical targets, it is important that we verify our progress in a way that is independent and transparent. In Fiscal Year 2006, three major technical milestones will be assessed using independent review:

- In hydrogen storage, we will determine the potential of cryogenic-compressed hydrogen tanks to meet DOE's 2010 targets.
- In fuel cells, we will evaluate high-volume fuel cell cost per kilowatt against our 2006 target of $110 per kilowatt and towards meeting the 2010 target of $45 per kilowatt.
- In hydrogen production, we will determine if the laboratory research is complete for $3.00 per gallon gasoline equivalent with distributed natural gas reforming technology. This technology will need to be validated later at full-scale.

In addition, high-volume manufacturing processes must be developed to lower the costs of hydrogen and fuel cells. Manufacturing R&D challenges for a hydrogen economy include developing innovative, low-cost fabrication processes for new materials and applications as well as adapting laboratory fabrication techniques to enable high-volume manufacturing. The Hydrogen Program is working with the Department of Commerce and other Federal agencies to create a roadmap for developing manufacturing technologies for hydrogen and fuel cell systems as part of the President's Manufacturing Initiative. The roadmap will help to guide budget requests in Fiscal Year 2007 and beyond. This work is part of the Interagency Working Group on Manufacturing R&D, which is chaired by the Department of Commerce and includes 14 Federal agencies. The Working Group has identified three focus areas for the future: nano-manufacturing, manufacturing R&D for the hydrogen economy, and intelligent and integrated manufacturing systems. Manufacturing R&D for the hydrogen economy will be critical in formulating a strategy to transfer technology successes in the laboratory to new jobs, new investments and a competitive U.S. supplier base in a global economy.

Successful commercialization of hydrogen technologies requires a comprehensive database on component reliability and safety, published performance-based domestic standards, and international standards or regulations that will allow the technologies to compete in a global market. Initial codes and standards for the commercial use of hydrogen are only now starting to be published. Research will be conducted in Fiscal Year 2006 to determine flammability limits under real-world conditions and the dispersion properties of hydrogen under various conditions and also to quantify risk. Through such efforts, critical data will be generated to help write and adopt standards and to develop improved safety systems and criteria. DOE is also working closely with the Department of Transportation in hydrogen codes and standards.

Conclusion

Mr. Chairman, the Department of Energy welcomes the challenge and opportunity to play a vital role in this Nation's energy future and to help address our energy security challenges in such a fundamental way. This completes my prepared statement. I would be happy to answer any questions you may have.

Mr. ISSA. Thank you, Mr. Faulkner. We will complete all three on the panel and then take questions.

We have also been joined by the gentlemen from Ohio, Mr. Kucinich.

Mr. Russell.

STATEMENT OF RICHARD M. RUSSELL

Mr. RUSSELL. Mr. Chairman, Ms. Watson and members of the subcommittee, I appreciate the opportunity to appear before you today to discuss the Federal effort in hydrogen research and development.

America's energy challenges must be met with dedicated leadership and advanced technologies to improve the production, distribution and use of energy. Beginning with his National Energy Policy Report in 2001, President Bush has established a clear path for our Nation to achieve a clean, secure and affordable energy future through advances in technology. The President has launched key research and development initiatives in hydrogen, clean coal, carbon sequestration, biomass, nuclear energy and fusion.

While this progress is encouraging, additional research is needed to make these technologies commercially viable. Commercial viability depends upon significant advances in protection, storage, distribution and use of hydrogen fuel.

Because all four areas present complex challenges, the overall Federal R&D effort has been engaged. To help ensure all pertinent agencies contribute to the President's objective in this area, the Office of Science and Technology Policy and OMB have identified hydrogen R&D as an interagency priority for the past several years.

To encourage collaboration among Federal agencies OSTP has established an interagency task force on hydrogen R&D. While DOE provides the leadership and most of the funding for the hydrogen fuel initiative and co-chairs the task force with OSTP, other Federal agencies also fund hydrogen-related R&D projects and demonstrations.

In fact, the Hydrogen Task Force has identified 22 focused R&D priorities for interagency collaboration. In the areas of fundamental research these include investigations of high performance, low cost catalysts for hydrogen production and fuel cells, novel materials for hydrogen storage, robust and cost-effective membrane materials and the molecular interactions of hydrogen and other materials.

These topics serve as focal points for collaboration among agency funding, basic research, including the Departments of Energy and Defense, the National Science Foundation, the National Institutes of Standards and Technology at the Department of Commerce, and the Research and Innovation Technology Administration at DOT.

Beyond fundamental research, the hydrogen task force coordinates activities associated with hydrogen pipeline and refueling; hydrogen turbines and internal combustion engines; solid oxide fuel cells; safety codes and standards; and several exploratory approaches to hydrogen production.

Additionally, we have recently begun a coordination group within the hydrogen task force devoted to work force issues, with the expected participation of the Departments of Labor, Energy, Defense,

Transportation, NASA, National Science Foundation and the National Institute of Standards and Technology.

In addition to developing an extensive inventory of hydrogen research activities, the hydrogen task force has developed a Web site, Hydrogen.gov., organized conferences and workshops on funding opportunities provided by the small business innovative research program and the small business technology transfer program and initiated plans for public forums to highlight nanotechnology breakthroughs that could enable the hydrogen economy.

Nanotechnology exemplifies how other interagency efforts are contributing to the hydrogen fuel initiative. With its ability to yield insight into structures and material at the molecular level, nanotechnology holds the key to understanding and solving many of these basic challenges.

To identify specific opportunities in this area, the National Nano Scale Science Engineering and Technology Subcommittee of the interagency National Science and Technology Council organized an interagency workshop in March 2004 on nano scale science research for energy needs.

This workshop and the recently published strategic plan for the National Nanotechnology Initiative have highlighted the potential for research in nano materials, nano-scale processes and next generation instrumentations to enable significant advances in hydrogen production, storage and fuel cells.

Since my time is up, let me quickly say that in addition to the task force, we also have a working group on manufacturing that is specifically spending time and effort on hydrogen manufacturing issues.

We also have two coordinating mechanisms; one for the national nanotechnology initiative and also one for the high performance computing initiative. Actually, it's called NITRD, Networking Information Technology Research and Development Program, to ensure that R&D that is occurring in other areas is also coordinated and that there's good interaction between DOE that funds the vast majority of R&D in the hydrogen sphere and all the other work that is going on throughout the Federal Government.

Thank you so much.

[The prepared statement of Mr. Russell follows:]

Statement of

The Honorable Richard M. Russell
Associate Director
Office of Science and Technology Policy

Before the

Subcommittee on Energy and Resources
Committee on Government Reform
United States House of Representatives

July 27, 2005

Mr. Chairman, Mrs. Watson, and Members of the Subcommittee, I appreciate the opportunity to appear before you today to discuss the Federal effort in hydrogen research and development.

America's energy challenges must be met with dedicated leadership and advanced technologies to improve the production, distribution, and use of energy. Beginning with his National Energy Policy Report in 2001, President Bush has established a clear path for our Nation to achieve a clean, secure, and affordable energy future through advances in technology. The President has launched key research and development initiatives in hydrogen, clean coal, carbon sequestration, biomass, nuclear energy, and fusion. These technologies, together with other elements of the President's energy plan, have the long-term potential to substantially reduce our Nation's dependence on foreign sources of energy while improving the environment. That is why it is so critical that Congress pass and send to the President's desk this week the comprehensive energy bill, which authorizes the President's key energy policies.

In concert with his research initiatives, the President has also advocated new energy efficiency standards for Federal and State governments and consumer products, tax incentives for the use of renewable sources of energy like wind and solar power, and tax incentives for the purchase of fuel-efficient hybrid vehicles. He has proposed extending the ethanol tax credit to encourage its continued use as an alternative source of fuel, and has promoted the safe expansion of nuclear energy, one of the cleanest forms of energy generation.

At a more fundamental level, the Administration has focused interagency research efforts in key areas such as nanotechnology, manufacturing, and high-end computing, in order to achieve the scientific understanding needed for substantial changes in our energy infrastructure. The important role of basic research in developing new energy systems and conversion processes has been highlighted in two reports by the President's Council of Advisors on Science and Technology.[1]

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[1] "The National Nanotechnology Initiative at Five Years: Assessment and Recommendations of the National Nanotechnology Advisory Panel," May 2005, and "Improving Efficiency in the Nation's Electrical System," February 2003.

One of the most promising opportunities for improving our energy infrastructure is hydrogen technology and America leads the world in hydrogen research. Two years ago, the President announced $1.2 billion over five years for the Hydrogen Fuel Initiative so that the first cars driven by today's children could be powered by hydrogen, and pollution-free. Successful development of technologies for the production, storage, distribution and use of hydrogen could dramatically reduce our dependence on foreign oil, as well as the emissions associated with fossil fuels.

Currently, two-thirds of U.S. oil consumption is in the transportation sector, and oil provides over 95% of the energy used by vehicles. By making a significant investment in research and development now, we can begin replacing our hydrocarbon-based transportation infrastructure with a hydrogen-based infrastructure. Leading the way in this effort is the Shell hydrogen fueling station here in Washington, DC, which the President recently toured on May 25, 2005.

At first, hydrogen will be produced primarily from natural gas, as it is today. In this case, net carbon emissions from fuel-cell vehicles on a well-to-wheels basis would be 25 percent less than gasoline-hybrid vehicles, and 50 percent less than today's conventional internal combustion engine vehicles. In the future, we expect that hydrogen would be produced from a combination of domestic energy sources and processes such as coal gasification with carbon sequestration, nuclear energy, photoelectrochemical water splitting, biological water splitting, wind-powered electrolysis, and biomass reformation. The Administration funds related research efforts in each of these technologies. For example, the Generation IV International Forum, with nine other nations as partners, is working on nuclear reactor designs that are safe, economical, secure, and able to produce both electricity and hydrogen. As hydrogen production shifts more to these alternative sources, our transportation sector could dramatically reduce emissions of air pollutants and greenhouse gases.

We envision a future in which hydrogen serves, along with electricity, as a primary energy carrier for the U.S. economy, produced from a diversity of domestically available feedstocks. The optimal combination of energy sources will likely depend on regional factors such as market availability, environmental constraints, and state regulations. Similarly, hydrogen distribution and delivery systems will most likely involve a combination of centralized production facilities and pipelines, local production at neighborhood fueling stations, and truck delivery to rural areas.

Achieving the hydrogen vision will involve several significant steps. A hydrogen infrastructure must be built that will enable convenient, safe, and affordable refueling across the Nation. Hydrogen-powered fuel cell vehicles must be safe, reliable and cost-competitive with the conventional vehicles that they replace, and they must have sufficient hydrogen storage to provide a 300-mile driving range without excessive size, weight, or cost. Industry codes and standards will be needed to guide the safe design, handling, and operation of hydrogen systems.

The President's Hydrogen Fuel Initiative, led by the Department of Energy (DOE), funds research in each of these areas, with the goal to enable an industry commercialization decision by 2015 to begin production of fuel-cell vehicles. So far, in FY 2004 and 2005, DOE has competitively selected more than $510 million in multi-year research and development (R&D)

projects, subject to appropriations, in the areas of hydrogen production, storage, distribution, and fuel cells. This includes $150 million over five years for hydrogen storage R&D at three Centers of Excellence, and $64 million in funding over three years in the Office of Science for basic research in nanoscale catalysts, novel materials for hydrogen storage and conversion, and hydrogen production from solar energy and biological processes.

Federal funding for hydrogen research is producing results. Technology development funded by DOE and industry has reduced the estimated cost of automotive fuel cells purchased in high-volume by 25% (from $275 per kilowatt to $200 per kilowatt) over the past three years. Development efforts have also reduced the estimated cost of delivered, natural gas-based hydrogen production from $5.00 per gasoline gallon equivalent in 2003 to $3.60 today. While this progress is encouraging, additional research is needed to make these technologies commercially viable. DOE's 2015 cost target for fuel cells is $30 per kilowatt, and the target for delivered, untaxed hydrogen is $2 – $3 per gasoline gallon equivalent. These goals are challenging. Other technical goals for the Hydrogen Fuel Initiative, such as energy density requirements for on-board hydrogen storage, will also require major technology advances. DOE has established a close collaboration among the Federal government, State governments, industry, academia, and the national laboratories to focus on the basic and applied research necessary to achieve these goals.

The overall Federal R&D effort has also been engaged to address these challenges. For the past several years, at the President's direction, the Directors of OSTP and the Office of Management and Budget have identified hydrogen R&D as an interagency budget priority. While DOE provides the leadership and most of the funding for the Hydrogen Fuel Initiative, other Federal agencies are also funding hydrogen-related research and development projects and demonstrations. The interests of each agency in hydrogen vary according to individual missions, but in general, these activities are relevant and complementary to the President's Hydrogen Fuel Initiative.

To encourage collaboration among the Federal agencies, OSTP has established an Interagency Task Force on Hydrogen R&D ("Hydrogen Task Force"). By working together, agencies can better accomplish their own missions as well as contribute to overall progress toward the goals of the President's initiative. The work of this group also ties in with interagency coordination efforts in nanotechnology, networking and information technology, and manufacturing, which are organized by OSTP through the National Science and Technology Council (NSTC) Committee on Technology.

The Hydrogen Task Force has developed an extensive taxonomy of hydrogen research activities and has identified key areas for interagency collaboration. For each priority, agency leads and participants have been designated to develop and implement interagency coordination plans. The Hydrogen Task Force has also developed a public website, hydrogen.gov; organized a conference workshop on funding opportunities provided by the Small Business Innovation Research and Small Business Technology Transfer programs; and initiated plans for a public forum to highlight nanotechnology breakthroughs that could enable the hydrogen economy.

The Hydrogen Task Force has identified 22 focused R&D priorities for interagency collaboration. In the area of fundamental research, these include the investigation of high-performance, low-cost catalysts for hydrogen production and fuel cells; novel materials for hydrogen storage; robust and cost-effective membrane materials; and the molecular interactions of hydrogen and materials. These topics serve as focal points for collaboration among agencies funding basic research, including DOE, the National Science Foundation (NSF), the Department of Defense (DOD), the National Institute of Standards and Technology (NIST) in the Department of Commerce (DOC), and the Research and Innovative Technology Administration in the Department of Transportation (DOT).

With its ability to yield insights into structures and materials at the molecular level, nanotechnology holds the key to understanding and solving many of these basic challenges. To identify specific opportunities in this area, the Nanoscale Science, Engineering and Technology Subcommittee of the NSTC organized an interagency workshop in March 2004 on "Nanoscience Research for Energy Needs." This and other topical workshops contributed to development of the Strategic Plan of the National Nanotechnology Initiative, published in December 2004, which outlines the major areas for interagency investment, including nanomaterials, nanoscale processes, and next-generation instrumentation. Research in these areas could enable significant advances in hydrogen production, storage, and fuel cells.

Similarly, high-end computing R&D, which is coordinated within the interagency Networking and Information Technology R&D Program, is a valuable tool that can provide insight into highly complex processes associated with hydrogen production, storage, and conversion. Complex computational simulations for solid-oxide fuel cells and proton exchange membrane fuel cells are being developed by Sandia National Laboratories. High-performance clusters or supercomputers will be used to model and analyze the operation (fluid flow and multi-dimensional transients) of fuel cell stacks at a detailed level. High-end computing can also be used to model microbial systems that might be modified for more efficient production of hydrogen through photosynthesis.

In addition to fundamental research, the Hydrogen Task Force coordinates activities associated with hydrogen pipelines and refueling, hydrogen turbines and internal combustion engines, solid-oxide fuel cells, safety, codes and standards, and several exploratory approaches to hydrogen production. For each of these topics, which are intentionally limited to areas of multi-agency interest, the Hydrogen Task Force serves as a forum for information sharing and collaboration on program plans, research projects, solicitations, and demonstrations. For example, DOE and the Environmental Protection Agency (EPA) have collaborated to improve their simulation and modeling tools. DOE, DOT, EPA, NIST, and NASA collaborate on hydrogen safety, codes and standards, and regulatory issues. DOE, DOT, NASA, NIST, and NSF are sharing data and planning research to better understand hydrogen embrittlement of pipelines and storage vessels. Several agencies are funding fuel cell vehicle and hydrogen fueling demonstrations, including DOE, DOT, DOD, EPA, and the US Postal Service, and these organizations provide updates about their progress and test results to the interagency group.

Additionally, we have recently begun a coordination group within the Hydrogen Task Force devoted to workforce issues, with expected participation from NSF, NIST, DOD, DOE, DOT,

NASA, and the Department of Labor (DOL). This group will discuss agency efforts such as the NSF Advanced Technological Education Program, DOL programs associated with the President's High Growth Job Training Initiative, and other workforce education initiatives. Within the framework of these programs, we plan to develop a performance-based, hands-on apprenticeship pilot program for technicians and engineers to receive training with fuel cell manufacturers.

Manufacturing R&D will be critical to transferring technology successes from the laboratory to the market, potentially leading to new jobs, new investments, and a competitive U.S. supplier base in a global economy. For this purpose, the NSTC Interagency Working Group on Manufacturing R&D, chaired by DOC, has selected hydrogen manufacturing, along with nanomanufacturing and intelligent and integrated manufacturing systems, as its top priorities. DOE and other agency participants recently organized a workshop for government, industry, and university stakeholders to develop a roadmap specifically for hydrogen and fuel cell manufacturing technologies. The roadmap will help to coordinate the Federal Government research agenda with industry and to guide future budget requests.

There are other coordination groups involving Federal agencies in the hydrogen arena, including the U.S.-initiated International Partnership for the Hydrogen Economy, which includes DOE, DOT, DOC, State Department, USAID, and representatives from 16 other nations that collaborate on hydrogen research and global codes and standards. Another significant group is the California Fuel Cell Partnership, which includes DOE, DOT, and EPA, along with eight automakers, four energy companies, and several State and local government agencies.

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

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

Mr. ISSA. Thank you. The best part, of course, is what you did extemporaneously. Thank you.

Dr. Lloyd, we look forward to your testimony.

STATEMENT OF ALAN LLOYD

Mr. LLOYD. Good afternoon, Mr. Chairman and members of the committee. Mr. Chairman, I would like to thank you very much for drawing attention to this issue and your interest in this issue of critical importance to the Governor of California and also the President himself.

I will be speaking from this Power Point document. I think California is committed to realizing a hydrogen economy. Just some background: We formed the California Fuel Cell Partnership back in 1999, which I will mention some more.

The California Hydrogen Highway Network, which was the key part of the Governor's environmental action plan when he came into office, focusing on the renewal policy, an important priority and part of a long term strategy.

We feel, in fact, that it is going to take a decade or two to get to a hydrogen economy and we need to start now. In fact, California's drive to a sustainable transportation future is based on our need to protect public health.

We had the Low Emission Vehicle Program in 1990 which focused on and continues to focus on super clean cars, alternate fuels, hybrids, battery electric vehicles and fuel cell vehicles.

Then we had the zero emission bus program in 2001 which is still in existence. Then we have the 2004 motor vehicle greenhouse gas regulation. So in California we have adopted an approach of regulations, partnerships, and incentives.

We look to the Hydrogen Highway Initiative. We are delighted to have DOE as a major partner as well as DOT and EPA at the Federal level, together with eight auto companies, four energy companies, two technology developers, State and local entities involved with the formation of the California fuel cell partnership designed to bring fuel cell vehicles to the market faster.

We have the stationary fuel cell collaborative emphasizing the stationary side. I think, again, with the Governor coming in exciting we launched as part of his environmental action plan the Hydrogen Highway Network. In fact, out of that was a charge to come up with a Blueprint Plan for the implementation.

You have before you, I think, a copy of the Blueprint Plan which was a culmination of efforts by over 200 stakeholders from all segments to work together to implement this policy, basically looking at a phased approach for vehicles and stations and in fact starting off with 50 to 100 stations in 2010 with up to 2,000 vehicles getting up to 20,000 vehicles and 250 stations in 2015 and 2016.

The emphasis is on renewable energies. Renewable is an important piece of what we are trying to do there. To show the State is committed, we have committed $6.5 million this year to kick off that program. That's the first year of a down payment which will get us some help toward infrastructure, help toward buying vehicles, both fuel cell as well as hydrogen IC engines there. That is already in the Blueprint Plan. So, the State is committed, working

with the Federal Government to move ahead and with the stakeholders.

In terms of the recommendations, you can see my recommendations. Fully fund the 2005 Energy Policy Act. Well, we didn't expect things to move so quickly. So, congratulations, in fact you have already implemented that.

Another recommendation is to work more closely with California in developing an integrated network of third-party accessible stations. That is an important piece because in order to be part of the California Hydrogen Network they have to be publicly accessible.

On the Governor's objectives by 2010, in fact you will be able to drive from D.C. to Baja, CA to British Columbia. Working with our partners there, you would be able to drive a hydrogen vehicle from D.C. to B.C. Then of course, 2010, Whistler, the Canadians have a plan to do that.

Level the playing field in competing for Federal dollars. I think that is another very important piece. Then, I think fully fund the programs for advanced renewable technologies in particular. I know these are areas we need to work on when the benefits of hydrogen can be gotten from a variety of sources.

Last, I show you the map there, I think for those who say that in fact it was too soon, I think the map showing you where we have some stations already. On the right hand side it shows the Governor kicking off the first station on the Hydrogen Highway Network at U.C. Davis with Professor Sperling and Vice Chancellor Heer.

Then we also see on the left hand side Honda turning over a fuel cell vehicle to the general public so that they can commute. The Spillano family is using it to commute from Redondo Beach to Irvine.

So, for those who say not today, it is here. Other companies are doing the same thing. We need that infrastructure. So thank you very much. We look forward to working with the Federal Government and with you.

[The prepared statement of Mr. Lloyd follows:]

Alan C. Lloyd, Secretary
California Environmental Protection Agency

TESTIMONY TO THE HOUSE GOVERNMENT REFORM SUBCOMMITTEE ON ENERGY AND RESOURCES

Realizing a Hydrogen Economy

July 27, 2005

Mr. Chairman and Members of the Committee, I appreciate the opportunity to testify today on California's efforts to advance hydrogen as a transportation fuel. California is striving to achieve a sustainable transportation and energy future through the use of regulations, incentives and partnerships.

California considers itself a leader in realizing the first hydrogen economy and has made a commitment to building a Hydrogen Highway that will lay the foundation for 50 to 100 hydrogen stations and 2,000 hydrogen vehicle by 2010. Building a hydrogen infrastructure is a long-term strategy and an investment in California's future. We have made a first-year down payment of $6.5 million to fund stations and vehicles. Using renewable resources is a core part of California's hydrogen future and a building block of our California Hydrogen Blueprint Plan.

We consider the Federal government to be a strong partner in developing a hydrogen economy in our State. The US DOE, EPA and DOT have actively participated in the California Fuel Cell Partnership, the California Stationary Fuel Cell Collaborative and served in prominent roles in the development of the California Hydrogen Blueprint Plan. Federal and State governments have different strengths and by combining our visions, we can create an environment that will allow free enterprise to flourish and eventually profit from clean technologies that benefit the public and the private sectors.

The Federal government has and should continue to promote research, development and demonstration (RD&D) of hydrogen technologies. Research and development, as pointed out in the March 2004 National Academies' of Science (NAS) Report, is a national priority. The report highlights several key areas where research funding should be increased, including fuel cells, hydrogen storage, distributed hydrogen infrastructure, carbon-free hydrogen (renewables and carbon capture and storage from fossil fuel technologies). Increased research funding is an absolute priority, particularly for renewable hydrogen sources and related infrastructure. However, we cannot achieve a hydrogen future by research alone, and early market deployment will be key to testing vehicles and fueling infrastructure. I have personally seen the benefit of the demonstration portion of RD&D to the development of technologies.

The NAS study is a call for government action to speed the hydrogen transition and needs to be considered in it entirety. All in all the committee is positive

about a hydrogen future and a sole focus on the cautionary provisions is short sighted. In fact, despite the challenges outlined in the Report, the Committee projects that a hydrogen future could be affordable including:

1. the fueling of a future fuel cell vehicle with hydrogen could cost no more than refueling today's gasoline cars and
2. the cost of a national hydrogen infrastructure is comparable to the cost of meeting new petroleum demand.

The US DOE should focus on and invest in California as a proving ground for hydrogen vehicles and an integrated fueling network to maximize resources and increase the rate of success.

CALIFORNIA'S DRIVE TO A SUSTAINABLE FUTURE

Committee question: ***What has prompted the State to move ahead with deployment of hydrogen technologies?***

Answer: Hydrogen is the only fuel that can fully address a spectrum of objectives necessary for sustainability. The objectives include a drive to achieve a zero emission transportation infrastructure, secure our energy future and bring high tech jobs to the State.

California's emphasis on hydrogen is part of a broader environmental and energy diversity program. The Zero Emission Vehicle program encompasses super clean cars, hybrids, battery electric vehicles, fuel cell electric vehicles, and alternative fuels. The Air Resources Board has adopted regulations that call for the reduction of greenhouse gas emissions from automobiles and light duty trucks. Such a portfolio of strategies is necessary to cover the near, medium and long term objectives of our State.

Although air quality in California has significantly improved over the past 50 years, it remains the nation's smoggiest state. Air monitoring records show that more than 90 percent of Californians breathe unhealthy levels of air pollution at some time during the year. Health studies show that one in seven children ages 6 through 17 in the state have been diagnosed with asthma. In 2003 more than 60 percent of the state's air pollution came from mobile sources such as cars and trucks that rely on gasoline and diesel fuels.

The burning of these fossil fuels produces pollution that not only damages human health but also generates greenhouse gases that contribute to the unsustainable climate change of the planet. In addition to air quality problems, the world is running out of easily accessible petroleum and almost 60 percent of the petroleum imported into the United States is from geopolitically unstable areas of the world.

California continues to tackle these challenges. To date, we have had one of the most successful "command and control" environmental protection programs in the world, and we persist in setting and meeting aggressive performance standards for emissions from new engines.

While this approach has been successful and needs to be continued, California must also look to the future in order to realize our health based air quality goals. And a fundamental strategy includes pursuing hydrogen as a transportation fuel.

Moving toward a hydrogen economy in California offers the possibility of energy independence and clean, sustainable transportation. Hydrogen when used to power vehicles produces very low levels of environmental impact. It can be produced through a variety of processes using a range of feedstocks, including natural gas, methanol, ethanol, biomass, and water. As an emerging transportation fuel, the promise of hydrogen is driving innovative design of high-efficiency vehicles that offer important energy diversification and environmental benefits.

The overwhelming majority of Californians support Governor Schwarzenegger's greenhouse gas emissions targets, hydrogen highway network, and million solar roofs initiative.

Source: PPIC Special Survey on the Environment.

THE CALIFORNIA HYDROGEN HIGHWAY NETWORK

Committee question: ***What concrete steps has California taken to realize a hydrogen economy?***

Answer:

- **Launched a State initiative to link hydrogen demonstration stations to create a third-party accessible, hydrogen fueling network**
- **Engaged over 200 volunteer experts to develop the California Hydrogen Blueprint Plan**
- **Adopted the California Hydrogen Blueprint Plan and its goals as California's hydrogen policy document**
- **Committed $6.5 million in California's 2005-06 budget for hydrogen technologies**

On April 20, 2004, Governor Arnold Schwarzenegger signed Executive Order S-7-04 calling for the development of the California Hydrogen Blueprint Plan (Blueprint Plan). On that same day, the Governor designated the University of California, Davis' hydrogen fueling station as "Station #1" of the California Hydrogen Highway Network.

In the months that followed, more than 200 volunteer experts engaged in the development of the Blueprint Plan. These volunteers represented a wide array of government agencies, private industry, academia, and environmental organizations. Each individual served on one of five separate "Topic Teams" which included Rollout Strategy, Societal Benefits, Economy, Implementation, and Public Education. Each team submitted an independent report; and the two-volume Blueprint Plan was compiled by an Executive Team. All members were motivated by a shared set of core values that defined the vision of a sustainable hydrogen economy for California, namely energy security, national security, a healthy environment, and economic growth and opportunity for California. The final report and recommendations were adopted by the Governor in May 2005.

The Blueprint Plan recommends a three-phased implementation strategy for establishing a hydrogen fueling infrastructure. Specific milestones include the introduction of 50 to 100 fueling stations, 2,000 hydrogen-fueled passenger cars and light-duty trucks, 10 heavy-duty hydrogen-powered vehicles, and 5 stationary or off-road fuel cell applications by 2010. Later phases include goals of 250 stations and up to 20,000 light-duty vehicles available for sale in the state. Similar accelerated objectives have been recommended for heavy-duty vehicles, stationary applications, and off-road vehicles.

Type of Hydrogen-Fueled Vehicle or Product	Number of Units Targeted / Estimated for Deployment (by Phase)		
	Phase 1: 50 to 100 Stations	Phase 2: 250 Stations	Phase 3: 250 Stations
Light-duty vehicles	2,000	10,000	20,000
Heavy-duty vehicles	10	100	300
Stationary and off-road vehicle applications.	5	60	400

The Blueprint Plan also recommends that the vehicles and stations contribute significantly to environmental benefits, specifically that they realize a 20 percent renewable energy goal for hydrogen production (in excess of the state's 20 percent Renewables Portfolio Standard goal) and a 30 percent reduction in greenhouse gas emissions.

Central to the achievement of the Blueprint Plan's goals is a siting strategy for hydrogen fueling stations. The stations currently operating in California have been placed for demonstration or research purposes such as those located at University of California sites or at the California Fuel Cell Partnership facility in West Sacramento. To ensure maximum use of future stations, it is essential that their placement be matched with the highest concentrations of vehicles. Initially, it is likely that these vehicles will be placed in fleets. The recommended approach is to build up a system of stations concentrated in California's main metropolitan areas such as Los Angeles, Sacramento, San Diego, and San Francisco. Under this scenario, auto manufacturers will be able to demonstrate the full viability of hydrogen technology and increase opportunities for Californians to choose to drive hydrogen vehicles and be able to refuel conveniently.

As we all know, achieving these goals will require funding from multiple sources. The most effective scheme will see the creation of public-private partnerships, industry collaborating with government. There is already considerable investment in California's hydrogen infrastructure—the first 39 stations are already being funded through existing partnerships such as those associated with the United States Department of Energy, the South Coast Air Quality Management District and the members of the California Fuel Cell Partnership.

Governor Schwarzenegger and the California Legislature have allocated $6.5 million in California's 2005-06 budget for government investment in up to 3 fueling stations, leases of 12 hydrogen vehicles for the state's fleet, and purchase of 2 hydrogen internal combustion engine shuttle buses to be used at a university or airport. All of these projects must meet energy and environmental goals that are more challenging than those recommended in the Blueprint Plan: 1) a 30% reduction in greenhouse gas emissions relative to today's infrastructure and 2) 33% of the hydrogen must be generated from renewable resources. In addition, the Cal/EPA Environmental Justice Committee will meet to discuss siting criteria for the hydrogen stations.

Number of people working in CA's renewables sector: 170,000
Amount of venture capital invested in clean technology in CA in 2003: $339 million

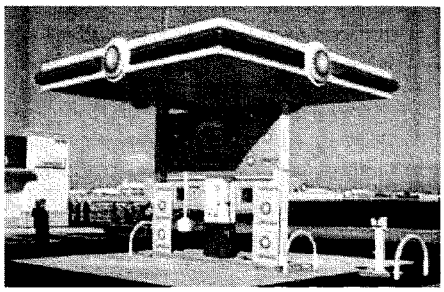
Source: Low Carbon Leader: California June. 2005

But additional activities are needed that can only be achieved through partnering—particularly research, development and demonstrations that combine the efforts of the United States' and California's governments.

PARTNERING FOR SUCCESS: THE U.S. GOVERNMENT AND CALIFORNIA

Committee question: ***To what extent has the Department of Energy helped or hindered the State's program?***

Answer:
California's hydrogen initiatives have positively benefited from the US DOE's RD&D program investments that were competitively bid and are congruent with the DOE national program.



LAX Hydrogen Station 1

The US DOE has significantly contributed to the success of California's efforts to build the first network of stations. DOE has indicated to me that $18 million of their 2004 budget and $25 million in their 2005 budget supports research, development and demonstration projects in California. In addition, DOE has offered their expertise in codes and standards, safety, communications, education, and energy efficiency and environmental benefits modeling. These contributions have been through working directly with State agencies, and via California research programs and National Universities located in California.

California is committed to working with our stakeholders and the Federal government to advance the development and acceptance of hydrogen technologies. Our commitment is in the form of regulations, incentives, policy introduction, demonstration coordination and communications. I believe California has the most forward looking and progressive hydrogen activities in the world because of stakeholder and Federal government investment, our experience with alternative fuels and our focus on environmentally sensitive technologies.

MOVING FORWARD—RECOMMENDATIONS

Committee question: ***What more could the Federal government do to support state initiatives like California's in realizing the hydrogen economy?***

Answer:
1. **fully fund the 2005 Energy Policy Act and provide tax credits for hydrogen based infrastructure projects**
2. **work more closely with California in developing an integrated network of third-party accessible stations**
3. **level the playing field in competing for federal funds**
4. **fully fund programs that advance renewable technologies**

1. Governor Schwarzenegger and I support the federal commitment to hydrogen technology in the 2005 Energy Policy Act. In addition, we hope the Conference Committee will include a tax credit for hydrogen-based infrastructure projects in the final legislation.

2. I suggest that the DOE and recipients of DOE hydrogen station awards work closely with my staff to build up the *network* of stations rather than continue to place stations that are only available to an isolated fleet of vehicles. The Federal government's investment in California hydrogen stations advances a hydrogen economy but does not always expand the California Hydrogen Highway Network because not all of the stations are third-party accessible. The legal and safety issues associated with third-party access need to be addressed if we are going to take our understanding of hydrogen commercialization to the next level.

3. The US DOE has laid out a program that is balanced and appropriate for the US. However, I have been discouraged that the *Hydrogen Vehicle Technology Demonstration and Validation Project* that is so important to California has been slowed down due to the proliferation of earmarks. The increased number of earmarks has changed the entire landscape of the process to compete and win DOE funding. Many stakeholders have expressed their frustration in competing for DOE awards when other competitors by-pass the usual process with earmarks awards. I do not believe the earmarks are in the overall best interest of DOE's programmatic goals or our country.

4. I encourage Congress to fully fund programs that develop renewable technologies because a sustainable hydrogen economy is based on renewably produced hydrogen.

Conclusion

Mr. Chairman and members of the Committee, California is committed to implementing Governor Schwarzenegger's Hydrogen Highway Network which is consistent with President Bush's vision of hydrogen as a long term strategy for the U.S.

Let me assure the Committee that California is serious about our commitment to realizing a hydrogen economy. We have taken the first important steps in building the California Hydrogen Highway Network and believe the time is right for the U.S hydrogen infrastructure to take root.

The challenges associated with implementing a hydrogen economy are significant but we cannot ignore the challenges associated with our present dependence on fossil fuel. The price of oil continues to rise and the competition for fossil fuel resources will only grow if China's economy develops on the same pathway that the US adopted. Not only is our energy security and position of prominence within the world economy at risk but so is the health of our citizens. Our inefficient fossil fuel dependence creates an unhealthy environment by poisoning our air, water and land. California is committed to addressing public health goals including urban air pollution and global climate change. We think hydrogen can address our environmental and energy security concerns.

We have an opportunity to leave our children with a safer way of life that doesn't include the worries associated with dependence on other countries for our energy supply. For all of the aforementioned reasons, I believe the challenges on the pathway to a hydrogen economy must be overcome.

I appreciate the invitation to speak to you today and look forward to continuing this dialogue in the future.

Invited Testimony
July 27, 2005

U.S. House of Representatives Government Reform Subcommittee on Energy and Resources

Alan C. Lloyd, PhD
Agency Secretary
California EPA

California is Committed

- Hydrogen Highway and renewable policy leadership
- Important priority and long-term strategy
- Time is right for the U.S hydrogen infrastructure to take root

California's Drive to a Sustainable Transportation Future

- 1990 Low Emission Vehicle program
- 2001 Zero Emission Bus program
- 2004 Motor Vehicle Greenhouse Gas regulations

California's Hydrogen Initiatives

- 1999 California Fuel Cell Partnership

California Fuel Cell Partnership

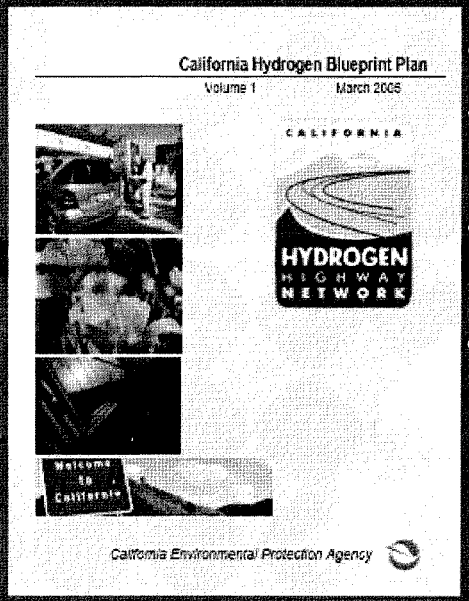
- 2001 California Stationary Fuel Cell

CASFCC
California Stationary Fuel Cell Collaborative

- 2004 California Hydrogen Highway Network

CALIFORNIA HYDROGEN HIGHWAY NETWORK
California Hydrogen Highway

The California Hydrogen Blueprint Plan



- California's hydrogen policy
- Phase approach to implement vehicles & stations
- Environmental targets
  emphasis on renewables
- 2005 budget = $6.5 million
  1st year down payment

Outlines the vision for a *Network* of hydrogen refueling stations

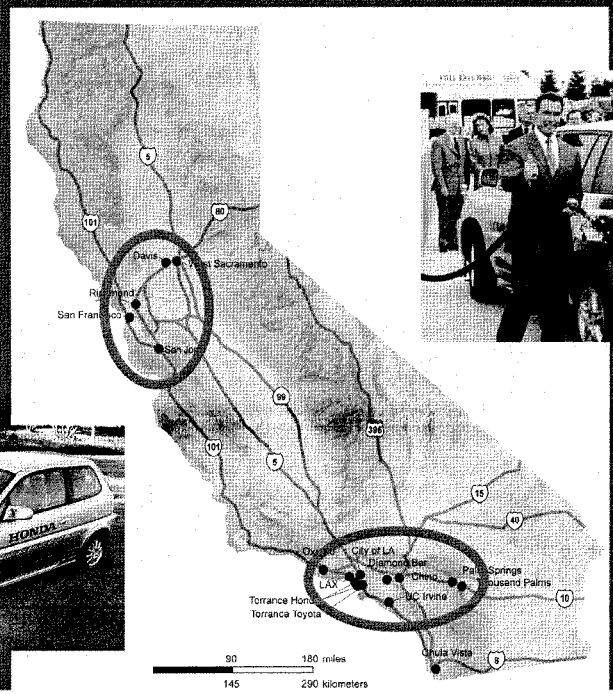
www.HydrogenHighway.ca.gov

Recommendations

- Fully fund the 2005 Energy Policy Act and provide tax credits for hydrogen based infrastructure projects
- Work more closely with California in developing an integrated network of third-party accessible stations
- Level the playing field in competing for federal funds
- Fully fund programs that advance renewable technologies

The Hydrogen Future is *Now* in California

CALIFORNIA
HYDROGEN
HIGHWAY
NETWORK



Mr. ISSA. Thank you.

Dr. Lloyd, I'm just going to ask you one question that came up during your testimony. I am a little concerned. Your definition of a level playing field, I would assume, is those States which contribute the most, take their own tax dollars and do advanced research should be at an advantage over those States who simply would like the money. Is that what you call a level playing field?

Mr. LLOYD. No. What I meant in that, Mr. Chairman, was in fact compete for the dollars, that everybody competes for the dollars. I recognize there is earmarking going on and I recognize we also participate in that because in fact if the rules aren't followed—and I know that's a tough issue from my colleagues at DOE. That is what I meant in that case.

Mr. ISSA. As a Californian, I always tend to have this feeling that since we led the way in clean air technology and our universities have done so much and we are contributing our own tax dollars that perhaps more of the research and development should be done in California than some other State that simply earmarks the dollars. I think we are pretty close to the same definition.

Mr. LLOYD. I think some of our neighbors in California seem to do very well.

Mr. ISSA. Yes, exactly. Thank you.

This is a more general question, but it is particularly important to the committee. There is a great deal of skepticism about whether the Department's time lines are attainable.

The national academies are calling them unrealistic and private industry has said that they should come sooner. Generally, somewhere between people who say it's too slow and too fast lies the truth.

But in this case, and Dr. Lloyd did a good job of saying so, hydrogen is here now, even if there may be a slower ramp up in actual production and delivery.

Well, Mr. Faulkner, the Department's view is that we have this long plan of test and evaluate and so on. There couldn't be two more different testimonies than what I saw here today.

We could do it faster. Now Honda is not ready to do 100 percent, but they are ready to do a much more similar rollout to what they have done in hybrid.

Well, we, Congress—myself included—and the administration, seem to be looking at this as a 2020 program. Could you help us reconcile that?

Mr. FAULKNER. Yes, sir. I think we all might not be that much different. Yes, there are hydrogen fuel cell cars out there, some of them being driven. They are not ready for mass production. They are too expensive for the average driver.

What we are talking about is looking at the longer term so that this does have mass market breakout potential. We are working in a partnership. I think that is important to emphasize because government won't be making these cars.

We are helping to do the high risk R&D that will help the companies that are actually going to be doing the work to make the money selling these things make the commercialization decision about 2015. That's the date that we and our private sector partners have focused on.

There will be instances of these vehicles being used in the marketplace, but they won't be available in showrooms for the regular person. I think about 2020 is the timeframe when we look at that starting to hit the marketplace. Then, of course, because vehicles take so long to turn over, it will take 10, 15 or 20 years to have that full impact be reached.

I think another point I'd like to make is that we have a lot of technology hurdles we are wrestling with. Research doesn't happen overnight. You have to start working on it today and that is why the President was so on target to start this 2 or 3 years ago because it does take years to work through these.

It is a lenghty process unless you have technology breakthroughs, but it does take time to work through the process.

Mr. RUSSELL. I would like to echo what Doug just said. I think the important point here is that you need something that is cost competitive on a commercial basis. Whereas the technology currently exists, it is not yet cost competitive.

There are some major issues that have to be overcome, technical issues that need to be overcome. DOE is doing an excellent job, as is the private sector, in terms of tackling those issues. But until you have a car that has a reasonable range and is cost competitive, it is not going to be ready for the general market.

Mr. ISSA. I am going to have to do something that I regret. I am going to have to recess for about 5 minutes. I hope you will give me the indulgence. I will offer an amendment in Judiciary and run back as fast as my sneakers can bring me.

Thank you for your patience.

[Recess.]

Mr. ISSA. The committee is now back in session. I am a man of my word, but I do need to get to the gym a little more often.

Dr. Sperling, who will be testifying in the second panel of the hearing, stated in his written testimony that there is no overall strategy to guide Federal spending on hydrogen research and development.

Can you respond to what is going to be said? Yes or no or I agree is fine.

Mr. FAULKNER. Well, I'm puzzled by that statement. I brought some documents here as props. We have the Hydrogen Posture Plan. We have the National Hydrogen Energy Roadmap. This program is one of the most reviewed and dissected programs I have seen in the government. I think it is well run. We have a plan that lays out on an integrated basis, not only in DOE, but in the government.

Mr. Russell here has a hand in looking at that. There are interagency reviews. Congress reviews these pretty carefully.

I think I would have to disagree with that statement.

Mr. ISSA. Do you have a different opinion?

Mr. RUSSELL. No, no, I would echo that. One of the benefits of being in the Office of Science and Technology Policy, we really do see all the budgets for all the various research initiatives that are going on.

I would say this one in particular is extremely well thought out and has been well charted into the future. I think the biggest sin-

gle issue is that we make sure that the funding we get maps to the funding we are asking for.

When I say we, I mean the Federal Government and the administration in particular because it has been well diagramed. So as long as we stay on track, as long as the funding that DOE ends up getting for the Hydrogen Program actually maps to the funding they need and the programs they need, I think we are going to be in good shape.

Mr. ISSA. Well, these documents, how do they specifically address the National Academy's concern for, among other things, the question of clear priorities to get you to that date there? I appreciate that there are multiple documents, Mr. Faulkner, and I really appreciate your saying various people who have a hand in it.

But I will say from my time in the private sector, I never could answer that the buck stops with everyone who has a hand in it. Where does the buck stop in meeting those timetables and coordinating them, assuming, as Richard said, that you have funding that matches your scheduled request?

Mr. FAULKNER. Well, when I was referring to people who have a hand in, I meant we have a partnership. We have not only the government, but we work very closely with our private sector partners.

The buck stops in my office, sir, at my desk. We have been put in charge of the initiative. We work through other parts of the Department of Energy. This has pretty clear time lines, goals and schedules laid out.

In terms of the National Academy, we have implemented 39 of the 43 recommendations in the Academy's report. So, we think we are on track with what they were looking at, what they were recommending. I should note the academy is getting ready to issue another report, next week, probably.

Mr. ISSA. Excellent. I think I will go to a slightly different tact which I think is equally important. Dr. Lloyd, is California moving too quickly to develop infrastructure relative to the time lines of the other two panelists?

Mr. LLOYD. No, I don't think we are. As a matter of fact, compared to the original program that the Governor outlined when he first came to office, the Blueprint Plan takes a more realistic approach of growing this from clusters and growing it outwards.

Obviously, we are working very closely with the private sector as well so we see what the vehicles and what the infrastructure is going to be. So, I think we have that about right.

Another aspect I want to indicate, getting back to an earlier topic, I think there are tremendous business opportunities with this technology, with hydrogen fuels technology and related technologies.

I think the Governor wants to take advantage of those in California. So, in fact we see that being driven forward not only by the major stakeholder, but also some of the minor ones as well.

Mr. ISSA. Following up on that, Dr. Lloyd, has California picked a preferred method of hydrogen production at this point?

Mr. LLOYD. Well at the moment clearly the preferred one would be looking at renewable technologies. In fact, in order to get the money through the legislature, they were very concerned about

that. The environmental justice community was very concerned about that.

But clearly we have a menu of options that you can use and in the nearer term you can use things like natural gas, but you can have electrolysis using renewables, you can look at biomass. So there is a variety of options. The preferred one is renewable technology, but clearly as we move forward we have to look at all of those sources.

Mr. FAULKNER. May I make a comment, sir?

Mr. ISSA. Yes. That is what we brought you here for.

Mr. FAULKNER. Well, I didn't want to interrupt you if you were getting ready to ask another question. It's too early to make that choice yet. Looking at the time line, 2015, 2020, we are looking at a range of different pathways of production.

As Alan Lloyd at the other end said, our preferred pathway at the end would be renewable production of hydrogen, but in the interim it would be natural gas that we are looking at.

Mr. ISSA. And following up with both of you, at the present time, D.C. to B.C., all likely rollouts will be 100 percent local creation of hydrogen from natural gas, is that correct? The Governor's filling station right now is natural gas?

Mr. LLOYD. Yes.

Mr. ISSA. Are there any filling stations in the design of D.C. to B.C., as we named it here that would be other than natural gas?

Mr. LLOYD. In fact there would be a variety of sources. Clearly, we have to work with our partners in Oregon and Washington and get that. I think you might ask Mr. Campbell, who is intimately involved with what is happening in Vancouver.

But no, we are looking at a variety of sources. No, it is not just all natural gas.

Mr. ISSA. At least some of them will be water-based electrolysis?

Mr. LLOYD. Will be renewable, exactly. In fact, if you look at places like Toyota and Honda, they also already have vehicles there are renewables using electrolysis, using solar to get the electricity.

Mr. ISSA. Mr. Russell, please describe the activities of the Hydrogen Interagency Research and Development Task Force. Tell us what this wonderful sounding long name means.

Mr. RUSSELL. The task force is co-chaired by both the Department of Energy and also OSTP. Actually, as it happens we also have, and I would like to introduce him, the co-chair of the task force, Dr. Kevin Hurst, who is behind me.

Essentially what we are trying to do is make sure that all the other agencies that are involved, everyone from EPA to even NASA have coordinated activities associated with their various pieces of R&D. So the task force has done everything from set up a Web site which I mentioned in my testimony, Hydrogen.gov., to hold workshops. Essentially, it is a coordinating mechanism which we use. So that is the primary purpose and that is what we do with it.

Mr. ISSA. One closing question from me, and this is the closing question because I recognize that the Senate is waiting for many of our panelists or will be.

At the present time, particularly in California, but on a national basis, we are using 100 percent of our domestic production of natu-

ral gas. We are importing relatively small amounts of liquefied natural gas.

However, plans are underway to import a fairly substantial amount of LNG. Would it be fair—and hopefully this is a yes or no—fair to say that any increase in consumption of natural gas in hydrogen-based automobiles, you know, any net increase that was not offset by some other reduction in the use of natural gas in some other area of our economy would leave us as or more dependent on an imported hydrocarbon than we are today?

If I am missing anything in the logic of "we are using it all, we are importing some and we are going to import more even if we don't make hydrogen cars," please say so. Because if we don't find another source for producing hydrogen we will be dependent on imported natural gas to fuel our vehicles which, oddly enough, comes from many of the same areas of the world as our oil does.

Is there any fallacy in that statement?

Mr. LLOYD. One of the things I would say for California, certainly in the nearer term there are lots of sources where we can in fact get the natural gas, and make hydrogen.

For example, lots of landfills where you can actually capture emissions from there, capture methane and turn it into hydrogen. There are lots of places where natural gas is clear. So, in the nearer term we are not keeping track of all the resource we have to tap that natural gas. In the longer term, then we have to look at a whole variety of options.

Mr. RUSSELL. There is an additional point which is slightly different than the way you asked the question, which is there's an efficiency game associated with fuel cell vehicles.

So, when you have a fuel cell vehicle, for the same amount of energy you have about 2.4 times the efficiency associated with that as compared to your standard automobile.

So, yes, you are right, you still are relying on natural gas, but you are relying on less of it than you are relying on oil. So, there definitely is an efficiency gain.

Even if we are using natural gas as our source of hydrogen, we are still gaining benefit both from a dependence on foreign oil and from an environmental standpoint.

Mr. ISSA. And you are saying 2½ times more efficient than if I simply had a compressed natural gas automobile?

Mr. RUSSELL. Well, that is actually a standard auto. If you are talking about a hybrid electric vehicle, it is 1.6 times as efficient. I don't have a natural gas vehicle comparison, but maybe DOE does.

Mr. FAULKNER. Just to add a couple of points to what they have already said, sir, we mentioned that natural gas was an interim fuel for production of hydrogen. It is not a long term permanent fix until we develop some of these other pathways to hydrogen.

The second thing is the national security issue of our increasing reliance on foreign oil, now it is in the high 50 percent of our use and climbing over the next two decades or more.

This is the only thing that will completely eliminate that dependence on foreign oil, the hydrogen fuel cell car.

Mr. ISSA. Well, I would like to thank all of you. I think you have done an excellent job of defending the work that the Federal Government is already doing.

Dr. Lloyd, I would be remiss if I didn't take advantage of having a key advisor to the Governor here to mention, when you brought up flaring of natural gas in California, just as one Californian to another, we flare that gas because the legislature prohibits it from being used, transferred for cogen and prohibits it from being put into the system if it is not natural gas burning automobile compliant.

Much of that could stop being flared with some small legislative changes that you have helped point out here today. I very much would love to see that natural gas captured and used in one of those two ways.

With that I would like to thank the panel. I realize that you are moving on to other panels on the other side of the Capitol.

Your testimony is very much appreciated. I'll say it again after the second panel, but you will have 20 legislative days to include any additional thoughts you have.

Many of the members of the committee will be submitting questions you may not have had today. With unanimous consent, which I'm sure I'll get right now, we will allow them to forward them to you and to revise and extend.

We will also be forwarding to you their opening statements. With that the first panel is dismissed with my compliments.

Mr. LLOYD. Thank you very much, Mr. Chairman.

Mr. ISSA. Will the second panel please come forward? I would like to thank the second panel for their patience. Hopefully, you saw that the Federal and State governments were not given a free pass here today. I promised them as they left that I would do the same back to private industry.

So you are aware, we are going to have a long series of votes at some point. I am going to do everything I can to be as expeditious as possible in getting through this. I would ask you to do the same.

There are not a lot of people to ask different questions, so you have that going for you, but when we adjourn, which will be about 10 minutes after the vote is called, it would be unreasonable to hold you through that long series of votes, so that will end the panel for today.

Since you have all been sworn in, and you were all mentioned and introduced earlier, we will now start with Dr. Burns and we will get through this as quickly as we can so you all get your statements in and our Q and A. Thank you.

STATEMENTS OF LAWRENCE D. BURNS, VICE PRESIDENT OF RESEARCH AND DEVELOPMENT AND STRATEGIC PLANNING FOR GENERAL MOTORS; DENNIS CAMPBELL, CEO, BALLARD POWER SYSTEMS; MUJID KAZIMI, DIRECTOR, CENTER FOR ADVANCED NUCLEAR ENERGY SYSTEMS, MASSACHUSETTS INSTITUTE OF TECHNOLOGY; AND DANIEL SPERLING, DIRECTOR, INSTITUTE OF TRANSPORTATION STUDIES, UNIVERSITY OF CALIFORNIA AT DAVIS

STATEMENT OF LAWRENCE D. BURNS

Mr. BURNS. Thank you, Mr. Chairman. I am vice president of research, development and strategic planning for GM and I am responsible for General Motors Fuel Cell Program.

We place very high priority on the combination of hydrogen and fuel cell technology because we see this combination as the best way to simultaneously increase energy independence, remove the automobile from the environmental debate, stimulate economic and jobs growth and allow automakers to create better vehicles that customers will want to buy in high volume.

I want to emphasize, high volume is crucial. It is the only way to meet the growing global demand for automobiles while at the same time realizing the energy and environmental benefits that we are seeking. So we must get the high volume.

Our fuel cell program is focused in three areas. We are focused on developing a fuel cell propulsion system that can be competitive, go head to head with conventional automotive propulsion systems, the internal combustion engine.

Second, we are demonstrating our progress publicly to let stakeholders experience first hand the benefits of the technology.

Finally, we are collaborating with energy companies and governments to ensure safe, convenience and affordable hydrogen available to our customers. This is key to enable a rapid transformation.

We are targeting to design and validate a fuel cell propulsion system by 2010 that can compete with the internal combustion engine. Let me clarify what that means: It is competitive on performance in terms of its power density, its speed and its range. It is competitive on durability, 150,000 mile life and at scale volumes it is competitive on cost.

That is an important step because without having the propulsion system being competitive we are not going to be able to get the high volume.

This is an aggressive timetable. It is clear that because of this aggressive timetable we are really signaling that this is an industry-led initiative and also we believe that the technology has matured to the point where this time it is indeed possible.

We have made significant progress on the technology in the last 6 years. We have improved our power density by a factor of seven. This means you can make the fuel cell components smaller, more efficient, which package in conventional automobiles.

We have significantly increased the durability, the cold start capability and reliability of our system. We have developed safe hydrogen storage systems that are beginning to approach the range that our customers will expect. We have made significant progress on cost reduction.

Now, this progress has convinced us that fuel cell vehicles have the potential to be fundamentally better automobiles on nearly all the attributes that our customers consider to be important. This is really key to enabling high volume.

With just one-tenth as many moving parts in a fuel cell propulsion system versus an internal combustion engine, we have also grown in our confidence that our vision design can indeed be cost competitive and durable.

We have also made excellent progress with our vehicle demonstrations. We have a fleet of six vehicles here in Washington, DC. We have had nearly 3,000 people take a ride or a drive in these vehicles so they can experience first-hand the technology.

The D.C. fleet is fueled by a Shell station out on Benning Road. Shell is our partner and it really is a small but very important step toward a hydrogen infrastructure. We collaborated with the U.S. Army in developing the world's first Army truck that is based on fuel cell technology.

We are part of the Department of Energy's program. We will be fielding 40 vehicles as part of that program. Very importantly, we have demonstrated what concepts, what the new automobile of the future can be like.

There are concepts called AUTOnomy, Hy-wire and Sequel. Sequel is the world's first vehicle that will be capable of going 300 miles between fill-ups, using a fuel cell.

Then we are partnering widely with Shell, Sandia, Dow, Department of Energy, Quantum, Hydrogenics. We are quite connected. We see the biggest challenge being a fast industry transformation to hydrogen and fuel cells.

The biggest challenge to that is the fuel and infrastructure. A major advantage of hydrogen is that it can come from so many different pathways, including renewables. As such it gives us a chance to relieve our 98 percent dependence on petroleum.

This is a big task, the infrastructure, but fortunately we are not starting from scratch. There are 50 million tons of hydrogen produced each year in the world today. Now if all of that was used in automobiles, that could fuel every automobile here in the United States, nearly 200 million automobiles.

Obviously, this hydrogen is being used for other purposes, for commercial purposes. The point I am trying to make here is that there is a lot of experience making hydrogen. It is experience that is safe. It is experience that is cost competitive for these commercial applications, which really encourages us that the infrastructure can fall into place.

We also don't have to build this infrastructure instantaneously. The entire car park of the Nation would take about 20 years to turn over. So, we could evolve the infrastructure in kind with that.

We would like to applaud the Department of Energy and the government for the initiatives that are in place on hydrogen. However, we think there is more that needs to be done to be ready for large scale demonstrations and ultimately mass market applications in the next decade.

We would like to see the Federal Government articulate a clear and concise and broadly sanctioned vision that goes beyond just what the DOE and the Department of Defense is doing, focused

both on technology and application. Clear and consistent communication to American people of this vision and the underlying rationale for it we think is really important to help transform the market.

The energy bill that is being considered we think is directionally quite good. But if we are really serious about transforming to a hydrogen economy, there is really a lot more that can be done in the coming years.

The auto industry alone is spending about $1 billion a year collectively on this technology. So, if the government would like to accelerate that, the government funding could be greater.

We welcome in particular the energy bill's increased funding of R&D. Yes, we have made dramatic progress on our first generation design, the one I referenced for 2010. But the real volume and the real benefits will come with second generation designs and beyond. So we would like to see the continued support of R&D for advanced materials for fuel cells as well as for hydrogen storage.

Market to man for fuel cell vehicles must also be encouraged. We think the price of hydrogen will be a critical factor and that Congress should act now to exempt hydrogen from fuel taxes to try to help hydrogen get on a level playing field with gasoline as we introduce it.

Then looking past 2010, we really have to start thinking about going beyond today's small demonstrations. We welcome any Federal fleet purchases that could go along to help encourage that. We think the energy bill, and we believe Congress should consider doing more and this would be an important bridge to commercial vehicles.

So to summarize, GMC sees hydrogen as the long term automotive fuel and fuel cell as a long term power source, our fuel cell program seeks to create clean, affordable, full performance fuel cell vehicles that will excite and delight our customers. We believe customers will buy these vehicles in large numbers and that society will reap the economic, energy and environmental benefits that would be related to that.

Thank you.

[The prepared statement of Mr. Burns follows:]

Lawrence D. Burns, Ph.D.
Vice President, Research & Development and Strategic Planning
General Motors Corporation

Testimony before the U.S. House of Representatives Committee on Government Reform
Subcommittee on Energy and Resources Hearing on Hydrogen and Fuel Cells
Rayburn House Office Building, Washington, D.C.
July 27, 2005

Mr. Chairman and Members of the Committee, thank you for the opportunity to testify today on behalf of General Motors. I am Larry Burns, GM's Vice President of Research & Development and Strategic Planning, and I am leading GM's effort to develop hydrogen-powered fuel cell vehicles.

GM has placed very high priority on fuel cells and hydrogen as the long-term power source and energy carrier for automobiles. We see this combination as the best way to simultaneously increase energy independence, remove the automobile from the environmental debate, stimulate economic and jobs growth, and allow automakers to create better vehicles that customers will want to buy in high volumes.

High volume is critical. It is the only way to meet the growing global demand for automobiles while realizing the large-scale energy and environmental benefits we are seeking.

GM's R&D program is focused on three areas:

- Developing a fuel cell propulsion system that can compete head-to-head with internal combustion engine systems.
- Demonstrating our progress publicly to let key stakeholders experience firsthand the promise of this technology.
- Collaborating with energy companies and governments to ensure that safe, convenient, and affordable hydrogen is available to our customers, enabling rapid industry transformation to fuel cell vehicles.

We are targeting to design and validate an automotive-competitive fuel cell propulsion system by 2010. By automotive competitive, we mean a system that has the performance, durability, and cost (at scale volumes) of today's internal combustion engine systems.

This aggressive timetable is a clear indication that fuel cell technology for automotive applications is industry driven (rather than government driven) and that this technology has matured to a point where such timing is indeed possible.

We have made significant progress on the technology:

- In the last six years, we have improved fuel cell power density by a factor of seven, while enhancing the efficiency and reducing the size of our fuel cell stack.

- We have significantly increased fuel cell durability, reliability, and cold start capability.
- We have developed safe hydrogen storage systems that approach the range of today's vehicles, and we have begun to explore very promising concepts for a new generation of storage technology.
- We have made significant progress on cost reduction through technology improvements and system simplification.

Our progress has convinced us that fuel cell vehicles have the potential to be fundamentally better automobiles on nearly all attributes important to our customers, a key to enabling high-volume sales. And with just 1/10th as many moving propulsion parts as conventional systems, our vision design has the potential to meet our cost and durability targets.

We have also made excellent progress with respect to vehicle demonstrations:

- Our six-vehicle fleet demonstration here in Washington, D.C. is now in its third year, with almost 3,000 people participating in a ride or drive. We also have other demonstration programs in California, Japan, Germany, and soon in China.
- The D.C. fleet is fueled at a Shell station equipped with a hydrogen pump. This is the first retail outlet dispensing hydrogen fuel in the U.S. and a significant, albeit small, step toward a hydrogen infrastructure.
- We collaborated with the U.S. Army on the development of the world's first fuel cell-powered military truck; it is currently being evaluated and maintained by military personnel at Fort Belvoir.
- We also will field 40 fuel cell vehicles, spanning two technology generations, as part of the Department of Energy's Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project. We are pleased to see that the Energy Bill affirms this demonstration. This is the right size program at the right time. It is large enough to generate real learnings about operating fuel cell vehicles, without being so large that it diverts the resources of automakers from our central focus on automotive-competitive technology.
- GM has also created the AUTOnomy, Hy-wire, and Sequel concepts, which demonstrate how new automotive DNA can transform our vehicles. Sequel, a five-passenger crossover SUV, is the first fuel cell vehicle capable of driving 300 miles between fill ups.

With respect to collaboration, we are working with key partners on virtually every aspect of fuel cell and infrastructure technology. Among our partners are Shell Hydrogen, Sandia National Lab, Dow Chemical, Hydrogenics, and QUANTUM Technologies as well as the Department of Energy, which includes the FreedomCar and Fuel Partnership involving Ford, Chrysler, and five energy companies.

The biggest challenge to a fast industry transformation to hydrogen and fuel cells is the fueling infrastructure. A major advantage of hydrogen is that it can be obtained from numerous diverse pathways, including renewable sources. As such, it promises to relieve our 98-percent dependence on petroleum as an energy source for cars and trucks.

Building a new fueling infrastructure is a formidable task. Fortunately, we are not starting from scratch. A global hydrogen infrastructure already exists today that produces 50 million tons of hydrogen per year – which equals the amount of hydrogen needed to fuel 200 million fuel cell vehicles! While this hydrogen is currently allocated to industrial uses, it shows that hydrogen can be produced and used economically and safely on a huge scale in commerce.

We also do not have to build the infrastructure overnight. It takes about 20 years to turn over the entire vehicle fleet, so it is possible to evolve infrastructure development in line with vehicle production.

GM has calculated that an infrastructure for the first million fuel cell vehicles could be created in the United States at a cost of $10-15 billion – about half the cost of the Alaskan oil pipeline (when its $8 billion price tag is converted into today's dollars). This infrastructure would make hydrogen available within two miles for 70 percent of the U.S. population and connect the 100 largest U.S. cities with a fueling station every 25 miles.

While this is a somewhat oversimplified calculation, it demonstrates that an initial hydrogen infrastructure would not be cost prohibitive. In fact, the cost is only a small fraction of the capital the oil industry says it will need to keep up with increasing demand for petroleum.

GM applauds the Department of Energy and the federal government for its hydrogen infrastructure initiatives. However, in our view, much more needs to be done if we are to be ready for the large-scale fuel cell demonstration programs and market growth that we envision for the next decade.

We would like to see the federal government articulate a clear, concise, broadly sanctioned vision that requires agencies beyond DOE and DOD to make hydrogen and fuel cell technology development and application priority areas of engagement.

Clear, consistent, ongoing communication to the American people of this vision and the underlying rationale for hydrogen and fuels cells is also vitally important to building public acceptance of fuel cell vehicles.

The Energy Bill now under consideration by Congress is directionally quite good, but if we are really serious about transforming to a hydrogen economy, there will be more to do in the coming years. The automotive industry alone is probably spending close to $1 billion per year on fuel cell technology. If government wants to accelerate progress, a greater investment is warranted.

We welcome in particular the Energy Bill's increased funding for R&D. Fuel cells energized by hydrogen fundamentally change the DNA of the automobile. While we have made dramatic progress toward a first-generation automotive-competitive system, like with any new technology, the real volume and benefits will be realized in second-generation designs and beyond. As such, we would like to see a significantly expanded national R&D initiative on breakthrough fuel cell materials, hydrogen storage, and hydrogen generation – leveraging the creative capabilities of our government labs, universities, and industrial research facilities – to help us move quickly to later-generation designs.

Market demand for hydrogen fuel cell vehicles must also be encouraged. The price of hydrogen will be a critical factor and Congress should act now to exempt hydrogen from fuel taxes until, perhaps, at least five million fuel cell vehicles are on the road. Since availability will also be an issue, a generous tax credit would ensure the investments necessary for development of hydrogen filling stations by mitigating the risks of these investments.

Looking past 2010, we must start thinking about moving beyond today's small-scale demonstrations. We welcome the federal fleet purchase program in the Energy Bill and believe Congress should consider doing more in this area. This would be an important bridge to commercially competitive vehicles and high-volume production.

To summarize, General Motors sees hydrogen as the long-term automotive fuel and the fuel cell as the long-term power source. Our fuel cell program seeks to create clean, affordable, full-performance fuel cell vehicles that will excite and delight our customers. We believe customers will buy these vehicles in large numbers and that society will reap the economic, energy, and environmental benefits.

I want to emphasize, however, that this is not just about car companies wanting to sell vehicles. In a very real sense, this is about nation building:

In the 19th century, the construction of the transcontinental railway gave rise to new industries and changed our country's economic destiny. In the 20th century, the development of the interstate highway system achieved similar dramatic results. The creation of a hydrogen-based economy is the 21st century's exercise in nation building. Leadership in hydrogen and fuel cell technology will underscore our pre-eminence in innovation and is absolutely vital to our future. It will ensure our ability to compete on a global basis, enable sustainable economic growth, and spur the creation of exciting new job opportunities for future generations of Americans.

GM is ready and eager to work collaboratively with government, energy companies, and suppliers to drive the hydrogen economy to reality.

Thank you.

Mr. ISSA. Thank you, Dr. Burns. If I can paraphrase your request, zero emissions, zero tax.

Mr. Campbell.

STATEMENT OF DENNIS CAMPBELL

Mr. CAMPBELL. Thank you, Mr. Chairman, members of the committee. My name is Dennis Campbell. I am the president and CEO of Ballard Power Systems. We are the exclusive fuel cell supplier to Ford Motor Co. and to Daimler Chrysler. To date, we have supplied 8 of the top 10 automotive manufactures.

Fuel cells offer a game-changing technology that can help us overcome some of the most pressing issues of our time, energy security, global climate change, urban air quality and long term energy supply. As with any disruptive technology, there are critics, those who prefer the status quo, those for whom the glass is always half empty. Today I would like to respond to the skeptics and the naysayers with a factual update that suggests the hydrogen economy is closer than many people think.

I will discuss three of the major challenges that must be overcome: reducing the cost, increasing the durability, and ensuring reliable startup in freezing temperatures.

Now, earlier this year Ballard released a technology roadmap as part of our plan to demonstrate commercially viable fuel cells by 2010. Our roadmap is fully aligned with the Department of Energy's 2010 automotive fuel cell goals.

From 1999 to 2003, we reduced the cost of our fuel cell by 80 percent, while achieving a tenfold increase in lifetime.

By 2004, we reduced our cost, adjusted for high volume production, to $103 per kilowatt. Our goal this year is to get down to $85 a kilowatt. We are confident that by 2010 we can meet the DOE target of $30.

The DOE has also set a commercial durability target of 5,000 hours, roughly the expected life of today's internal combustion engines, 150,000 miles. We are on track to meet that goal.

Last year we demonstrated automotive technology with a lifetime of 2,200 hours. Ballard-powered fuel cell buses in Europe have surpassed more than 2,500 hours of operation and our stationery cogeneration fuel cell for Japan has achieved more than 25,000 hours of lifetime.

Now, a third technical challenge is to improve the ability of our fuel cells to start in freezing temperatures. Last year we demonstrated the ability to start at minus 20 degrees Celsius, reaching 50 percent power in 100 seconds. Our goal for 2010 is to demonstrate startup for minus 30 in 30 seconds.

Now, a key enabler of this progress is the demonstration of fuel cell vehicles in the hands of everyday customers. Since 2003, Ballard fuel cells have been powering 30 Mercedes-Benz transit buses in daily revenue service in 10 cities in Europe. More than 3½ million passengers have already experienced the advantages of clean, quiet fuel cell transportation.

The Department of Energy's fleet validation program takes our field experience to the next level. Ballard, through its automotive partners, Ford and Daimler-Chrysler, as part of the DOE initiative,

will be powering approximately 60 vehicles in various locations throughout the United States.

The effective demonstrations are critical, but the more important determinant of when fuel cells can be introduced to the mass market will be the will and the commitment of government. There is no better investment for government to make in the health and welfare of its people than an all-out Apollo-like commitment to hydrogen and fuel cells.

The President's hydrogen initiative has galvanized industry and government in support of the hydrogen economy and continues to facilitate public and private collaboration. The pending energy bill's R&D demonstration programs, if fully funded, will strengthen the President's initiative and will provide a vital boost to fuel cell commercialization.

Now, it's a great start, but considering the stakes, I urge Congress to do more. An effective national strategy to accelerate the hydrogen economy must also include a transition to market plan. Only government can overcome the classic chicken and egg problem and kick-start the transition to fuel cell power.

We applaud the proposed $1,000 per kilowatt tax credit for stationary fuel cells. For automotive fuel cells, the framework of an effective transition to market program is present in legislation sponsored earlier by Senators Dorgan and Graham. It is also captured in the energy bill's vehicles and fuels provision.

In closing, I strongly recommend that Congress significantly increase funding for the fuel cell vehicle procurement program. A vigorous procurement program targeting fuel cell vehicles for Federal and State fleets must be in place alongside R&D and demonstrations as a third component of a national strategy to accelerate the hydrogen economy.

A clear commitment by Congress to make a specific and sizable annual outlay in fiscal years 2010 to 2015 for State and Federal fuel cell fleets would support the volume production necessary to drive costs down, stimulate the buildout of a hydrogen infrastructure, draw additional private capital into the sector and provide the American public with a large scale introduction to the hydrogen economy.

There is no doubt the challenges are real, but they can and they will be met. Thank you for the opportunity to appear before you today. I look forward to any questions that you may have.

[The prepared statement of Mr. Campbell follows:]

Dennis Campbell, President and CEO
Ballard Power Systems

Testimony before the U.S. House of Representatives Committee on Government Reform
Subcommittee on Energy and Resources
Rayburn House Office Building, Washington D.C.
July 27, 2005

Mr. Chairman, Members of the Committee, my name is Dennis Campbell and I am the President and CEO of Ballard Power Systems. Thank you for the opportunity to speak with you today on a subject of central importance to today's pressing energy, economic, and environmental challenges.

Ballard is recognized as the world leader in developing and manufacturing proton exchange membrane or PEM fuel cells. We've been developing PEM fuel cells since 1983 and hold nearly 1,000 patents, granted and pending, on some of the most fundamental fuel cell technologies.

We are the exclusive fuel cell supplier to Ford Motor Company and DaimlerChrysler and to date have supplied eight of the top 10 automotive manufacturers. Today, Ballard fuel cells power more customer demonstration vehicles than all other fuel cell developers combined.

Based on our more than 20 years of research, development and extensive over-the-road experience, we've concluded – and I believe each of the major automotive manufacturers would agree - that hydrogen fuel cells will be the automotive powertrain of the 21st century.

Fuel cells have the power to transform our world because they offer a comprehensive solution to the most pressing problems of our time: energy security, global climate change, urban air quality, and long-term energy supply.

In addition to these obvious benefits, a fuel cell powered automobile is also simpler to build, inherently more reliable with fewer moving parts, and has the potential to be feature rich, more versatile and more fun to drive.

At Ballard our corporate vision statement is "Power to change the world". While that may sound like a lofty statement, there are those who would take it a step further and state that fuel cells in fact, have the power to save the world.

The fact is, the hydrogen economy is not just some Utopian dream, it is an opportunity that is within our reach. The building blocks are here today, and we have clear line of sight to solutions that will meet the remaining technical challenges.

As with any disruptive technology, there are legions of critics, those who prefer the status quo, those for whom the glass is always half empty.

When I was a student at the University of Oklahoma in 1967, the Senator from New York came to our campus for a talk. That night, Bobby Kennedy said something that has stayed with me all these years and continues to inspire me today. He said:

"Some men see things as they are and ask 'Why?'
I dream things that never were and ask, 'Why not?'"

At Ballard we are focused on "why not." We're focused on solving problems, on advancing the technology, on meeting the challenges.

We are responding to those who claim that fuel cell technology is, and will remain, prohibitively expensive; that onboard fuel storage is too difficult; that a hydrogen refueling infrastructure is too much trouble; or that it takes too much energy to produce hydrogen.

We're focused on providing evidence, not opinion. Let me offer some data to set the record straight.

Last year, before the House Science Committee, Dr. Joseph Romm, a leading critic of fuel cell technology, claimed that PEM fuel cell costs were about 100 times greater than the cost of a comparable internal combustion engine and that a major technology breakthrough would be needed in transportation fuel cells before they would be practical.[1]

The truth is that from 1999 to 2003, at Ballard we reduced the cost of our fuel cell by 80% while achieving a ten-fold increase in lifetime. By 2004, we reduced the cost of our fuel cell, adjusted for high volume production, to $103 dollars per kilowatt – that's only a bit more than three times higher than the commercial target the Department of Energy has set for 2010. Our goal this year is to get down to $85, and we're confident that by 2010 we can achieve DOE's target of $30 per kilowatt.

This is not unlike developments in the computer industry. In 1956, a gigabyte of memory cost $10 million. By 1980, the cost had been reduced to $193,000 per gigabyte. Today, the cost is about $1.15.

The hydrogen delivery infrastructure, cited by many critics as an insurmountable obstacle, is merely an engineering problem. There are already more than 100 fueling stations in place around the world. The estimated cost for broad deployment of a hydrogen fueling infrastructure in the US is variously estimated at between $10 and $20 billion - not much more than the $11 billion that the industry reportedly spends each year to simply maintain its present gasoline delivery system.

[1] Dr. Joseph Romm before the House Science Committee, March 3, 2004.

With respect to on-board storage of hydrogen, progress is being made with higher pressure tanks, purpose built vehicles, and the investigation of solid storage media.

Governments are assembling the building blocks of the hydrogen economy in fuel cell vehicle demonstrations throughout the world. Through these demonstrations, citizens are gaining exposure to hydrogen and fuel cell vehicles and the promise of clean, energy independent transportation.

One such demonstration is the Department of Energy's Fleet Validation program. Ballard, through its automotive partners Ford and DaimlerChrysler, will be powering approximately 60 vehicles in this initiative in various locations throughout the U.S., generating important data and experience that will directly advance the technology.

Another highly successful demonstration program is the European Fuel Cell Bus Project. Since 2003, Ballard fuel cells have been powering 30 Mercedes-Benz Citaro buses in daily revenue service in 10 different cities. This program is co-financed by the European Union.

To date, more than 3.5 million passengers have ridden these Ballard powered buses, putting them in direct contact, *today*, with clean, quiet and efficient hydrogen-fueled transportation. In London, Mayor Ken Livingstone embraces these fuel cell buses as part of his initiative to reduce ambient noise levels in the city.

In addition to the European program, six other Ballard powered transit buses are operating in Perth, Australia and Santa Clara, California with three more scheduled for Beijing later this year.

Through these and other demonstrations, Ballard fuel cells are powering more than 130 vehicles on four different continents, approximately three quarters of all publicly demonstrated fuel cell vehicles on road today.

As we move from demonstrations to a commercially viable fuel cell product for the automotive sector, there are four key technical challenges to be overcome: reducing the cost, increasing the durability, ensuring reliable startup in freezing temperatures, and doing so within the available package space.

Ballard has a plan to overcome each of these challenges... what we call our technology "road map", our public commitment to demonstrate commercially-viable automotive fuel cell stack technology by 2010. This "road map" is fully aligned with the DOE's published commercial targets for this technology.

Let me first address fuel cell cost. Meeting DOE's 2010 cost target of $30 per kW will ensure that a fuel cell engine is cost competitive with today's internal combustion engines. There are a number of factors that affect fuel cell cost. Two of the most challenging are the amount of platinum used in the catalyst, and the type of membrane used in the fuel cell construction. Ballard has done significant research and development to reduce the amount of platinum we use. In 2004 we demonstrated a 30% reduction without compromise to performance, efficiency or

durability. We are also looking at a number of membrane chemistries and constructions to significantly reduce the cost of this critical component. We believe we are on track to achieve the DOE target of $30 per kilowatt by 2010.

Durability is the second key technical challenge we face. The DOE has set a 2010 commercial target of 5,000 hours – about 150,000 miles which is roughly equivalent to the lifetime of today's internal combustion engines. As with the cost challenge, membrane design and material is a key factor in fuel cell lifetime. Last year, we demonstrated automotive fuel cell technology with a lifetime of 2,200 hours. Many of the Ballard-powered fuel cell buses operating as part of the European Fuel Cell Bus Project have achieved more than 2,500 hours of operation. We have a stationary fuel cell – our cogeneration system for residential usage in Japan - that has achieved more than 25,000 hours of lifetime. We are confident that we can deliver the DOE target of 5,000 hours by 2010.

The third technical challenge is to improve the ability of our fuel cells to start in freezing temperatures. The electrochemical reaction within a fuel cell produces water and heat. Managing that water in sub-freezing temperatures is essential to a successful start-up. Our advanced simulation tools and testing methods have provided us with insight and a fundamental understanding of how water behaves through the various cycles of fuel cell operation. Last year, we demonstrated technology that was able to start at -20° Celsius, reaching 50% of the rated power within 100 seconds. Our goal for 2010 is to demonstrate start-up from -30° Celsius, reaching 50% of the rated power in 30 seconds. The DOE target for 2010 is -20° Celsius, reaching 50% of the rated power in 30 seconds.

Power density, is an important boundary condition that constrains the previous three goals to ensure that the solutions can be packaged within the limited vehicle space available. Last year, we demonstrated fuel cell technology at 1,200 watts per liter net. The DOE's 2010 commercial target is 2,000 watts per liter net. As in the case of freeze start, we've actually set a more stringent target for ourselves, at 2,200 watts per liter net, based on our customers' requirements, and we're confident that we can achieve that.

To summarize: we know what the technical challenges are, we have multiple technology paths that we are pursuing, and we are confident that we will demonstrate commercially-viable automotive fuel cell stack technology by 2010.

The single most important determinant of when fuel cells will be commercially available for automotive application is the will and commitment of government. If the role of government is to protect and serve its people, there is no better investment for government to make than an all-out, Apollo-like commitment to hydrogen and fuel cells.

The President's Hydrogen Initiative has galvanized industry and government in support of the hydrogen economy, and continues to facilitate public-private sector collaboration.

Though I believe a higher overall funding commitment is appropriate, the pending energy bill's important R&D and Demonstration programs will strengthen the President's initiative and, if fully appropriated, provide a push at a crucial stretch along the commercialization timeline.

Yet I urge Congress to take a further step. A national strategy to accelerate the hydrogen economy must not only have strong R&D and Demonstration programs but also a robust transition to market plan that provides a bridge to commercialization. Only government intervention can overcome the classic chicken and egg problem and kick-start the transition to a hydrogen economy. The proposed $1,000 per kilowatt tax credit for stationary fuel cells is a good beginning – but more must be done to support vehicular fuel cell introduction.

The framework of an effective transition to market program for fuel cell *vehicles* is present in legislation sponsored earlier this year by Senators Dorgan and Graham, and is also captured in the energy bill's Vehicles and Fuels provision. I strongly recommend that Congress elevate, expand, and significantly increase funding for this procurement program for fuel cell vehicles. A strong procurement program aimed at fuel cell vehicles for federal and state fleets must be in place, along side R&D and Demonstrations, as a third component of the national strategy to accelerate the hydrogen economy.

Broadcast early enough and with sufficiently clear guidelines, a clear commitment by the Congress to make a specific and sizable annual outlay for the fiscal years 2010 to 2015 on federal and state fleet procurement of fuel cell vehicles would: (a) support early volume production by automotive OEMs and suppliers that is necessary to drive cost down; (b) support the build out of hydrogen infrastructure; (c) draw additional private capital into the sector, and (d) provide the American public with a large scale introduction to the hydrogen economy.

In closing, let me say that the challenges are real – but they can and will be met.

Thank you for the opportunity to appear before you today. I look forward to any questions you may have.

Mr. ISSA. Thank you, Mr. Campbell.
Mr. Kazimi.

STATEMENT OF MUJID KAZIMI

Mr. KAZIMI. Mr. Chairman, it is a pleasure for me to have an opportunity to discuss with you the subject of hydrogen energy. As noted, I was a member of the National Research Council Committee on Alternatives and Strategies for Future Hydrogen Production and Use which published a report entitled "The Hydrogen Economy: Opportunities, Costs, Barriers and R&D Needs."

This committee recommended several things, but the main ones were as follows: Hydrogen can, with appropriate development of technology, fundamentally change the U.S. energy outlook, both because of its impact on imported energy sources and its impact on the potential climate change.

Second, there are formidable technical hurdles to overcome, including economic, social and political challenges. There are many options for the production, distribution, storage and use of hydrogen, but none of them satisfies the full combination of desired attributes. The R&D program should establish criteria to judge the potential technical and economic performance for each.

Finally, the United States must maintain a robust, balanced energy program in areas other than hydrogen to maximize the likelihood of meeting that national goal. Since the issue of the NRC report, several developments took place, you mentioned them in your opening statement, which simply added to the urgency of addressing the issue.

So, today we have a higher priority for the development of alternative energy that relies on domestic sources and do not increase carbon emissions. For the long run, that means clean coal, that is coal with sequestration of the carbon dioxide, nuclear energy and renewable energy.

The NRC committee has made recommendations to improve the DOE program for hydrogen and by and large the DOE has followed with a good number of changes in order to accommodate the NRC recommendations.

However, there are certain areas that are lagging that are important to pay attention to. I would like to mention a few. First, the recommended system models to assist the evolution from near term technology to long term technology is still being planned. That leaves us now working on the evolution of our clean energy system in a piecemeal as opposed to a coordinated fashion.

Second, we need an assessment of alternative methods to produce liquid fuel that might require hydrogen for their production but that do not alter the car power train or the infrastructure needed for distribution. I mentioned two examples that might be competing with the fuel cell approach that we have heard good progress reports on.

One is the use of unconventional oil reserves that we have. In North America, we have approximately 1,500 ExaJoules in oil and that are sands, in shale and tar sands. Whereas, in the entire Middle East they have about 2,500 ExaJoules of that kind of resource.

With that amount of resource available to us, I can't imagine that we would not be using it. The heat and hydrogen needed to

sweeten the shale and tar sand oil could be produced from sources other than natural gas that is being used today, such as renewables and nuclear sources to avoid the carbon emission to the atmosphere. This will not be a total solution for the carbon emissions, but it will reduce the overall carbon emissions to the atmosphere.

The second approach that I would like to mention is the question of producing synthetic liquid fuels using carbon dioxide that is captured from electric power plants. The technology exists. It needs some development and I think it would be worth it.

Finally, I would like to say that the issue of production of hydrogen has not been given enough attention. I am very familiar with the nuclear hydrogen production program and I see some hesitation about going forward with a demonstration of the appropriate technology today.

While we know that we need a new type of reactor that can produce high temperatures in order to facilitate efficient production of hydrogen, we have none in the United States today. Meanwhile, Japan already has one that started operation in 2001 and has already produced hydrogen using high temperatures approaches in the order of 30 meters per hour as of last December. Their program is progressing to about 1,000 times as much, which they would like to accomplish by 2007.

So, I would like to urge that DOE put a higher priority on the development of the high temperature reactors and the demonstration of the ability to integrate such reactors with the means for production of hydrogen.

Thank you.

[The prepared statement of Mr. Kazimi follows:]

The Road to the Hydrogen Economy: Beyond the NRC Report

Testimony of
Mujid S. Kazimi
Professor of Nuclear Engineering and Mechanical Engineering
Director, Center for Advanced Nuclear Energy Systems
Massachusetts Institute of Technology
to
Subcommittee on Energy and Resources
Government Reform Committee
United States House of Representatives

July 27, 2005

The Honorable Chairman and Members of the Committee:

It is a pleasure for me to be called before you to discuss the subject of the R and D program of DOE for development of hydrogen energy– a matter of considerable importance to the future of the US energy security, as well as to our ability to reduce the risk of continuously raising the level of carbon emissions to the atmosphere, thus triggering fundamental changes in the Climate.

Main Recommendations of the NRC Committee on Hydrogen

In early 2004, the National Research Council Committee on Alternatives and Strategies for Future Hydrogen Production and Use published a report " The Hydrogen Economy: Opportunities, Costs, Barriers, and R &D Needs". As a member of that Committee, I had a chance to get acquainted with the scope of DOE's program that translates the President's initiative on Hydrogen into funding of research, development and deployment activities.

The main conclusions of the NRC committee were as follows:

- Hydrogen can, with appropriate development of technology, fundamentally change the US energy outlook by reducing the need for imported energy sources while also reducing the emissions of carbon dioxide and other regulated emissions.
- There are formidable technical hurdles, and non-technical hurdles to overcome, including economic, social and political challenges.
- There are many options for the production, distribution, storage and use of hydrogen, but none of the options satisfies the full combination of desired attributes. The R and D program should establish criteria to judge the potential technical and economic performance in each area, and allocate resources to

demonstrate the more promising area, while allowing the basic and exploratory ideas.

- The US must maintain a robust, balanced energy RD&D program in areas other than hydrogen, to maximize the likelihood of meeting the national goals.

Since issuing the NRC report, several developments heightened the need to push forward with preparing technologies and standards that maximize the chances for use of energy sources other than oil for our transportation needs. For a starter, the price of oil has more than doubled, while it will continue to fluctuate, it is not likely that it will ever go back to the level of 25 $/barrel that the NRC used in its assessment. Similarly, the price of natural gas has climbed from $3.5 per MBTU to more than $6. The price hike is indicative of the world-wide balance of supply and demand for these resources, which is likely to get worse with the growth of the economies of the largest two countries in the World: China and India. Realizing that the effective price of oil at $60 per barrel is only equivalent to what it used to cost at the end of the 1980s, it is not likely that it will come down much. That is the bad part. On the other hand, the current price of gasoline make it easier to introduce alternative technologies in the transportation sector.

Another important development is the certification of the Kyoto agreement by the requisite number of countries to put it into effect, which now will bring more pressure on our industry to offer technologies that are compatible with the desire by most of the World to limit the carbon emissions to the atmosphere.

A third important development is the rise in the level of uncertainty about the security of supply of oil and gasoline, due to the rise in the level of violence and terror in the Middle East, the region responsible for exporting most of the oil in the world. Whatever desirable objectives may have been behind invading Iraq, the outcome has been to increase the turmoil in that country, and potentially in neighboring oil rich ones, thus increasing the chances for interruption of oil flow to the rest of the World.

So, today there is a higher priority for the development of alternative energies that rely on domestic sources and do not increase carbon emissions. That means clean coal (i.e coal with sequestration of CO_2), nuclear energy and renewable energy. While in the last two decades we have seen a huge rise in the use of natural gas for energy consumption, it is clear that if this continues, the imports of gas would rise in time to reach the level of discomfort that we have today with oil, where more than 55% of our consumption depends on non-American sources. Furthermore, much of the imports would be in the form of liquefied natural gas (LNG), which is more expensive than pipeline gas from Mexico and Canada.

The R and D Recommendations

The NRC Committee emphasized the need for development of a systems analysis capability to identify the best options for the short, medium an long term policies and technologies to expedite the time at which hydrogen could be widely used in society.

The key priorities for the R and D objectives, as recommended by the committee, were

1) Development of cost effective and environmentally desirable mobile fuel cells that use hydrogen to power light duty vehicles.
2) Development of durable and safe hydrogen storage systems.
3) Development of the infrastructure needed to provide hydrogen for light duty vehicles throughout the country.
4) Reduction of the cost of hydrogen from CO_2-free sources, such as renewable and nuclear electricity plants, and increase the effort for efficient and inexpensive electrolyzer development.
5) Solving the CO_2 capture and sequestration issues, economically and safely.

The Committee advised that the area of hydrogen infrastructure deserved increased funding and support, especially for the transition period during which overcoming the hydrogen and fuel cell vehicle "chicken and egg" problem will need to be overcome. In particular:

- To focus on materials issues in distribution and storage of hydrogen.
- To Create better linkages between programs in large-scale and small-scale hydrogen production
- To Clarify conditions under which large-scale and small-scale hydrogen production will become competitive, complementary, or independent
- To explore new concepts for hydrogen delivery

The committee recommended strengthening the development of standards for safe handling of hydrogen and to increase the public understanding of the safety issues. There is a need to ensure that in the production, storage and shipping of hydrogen sufficient testing has been done to resolve safety issues ahead of large scale commercial use of hydrogen in industry. Similarly for the transition period in which hydrogen may be produced at filling stations either by electricity or using natural gas reformation

DOE has made good progress in many ways in reshaping its program along the lines recommended by the committee, but not in all the needed areas. On the positive side:

1- Increased coordination among DOE various offices (EERE, FE, NE, BS, and SC).
2- Increasing the total budget for the core hydrogen and fuel cell program from $144M in FY04, to 169M in FY05, and a budget request for FY06 of $183M.
3- Refocusing some of the research, for example away from on-board reformation of gasoline, and into other more promising areas, such as on high pressure hydrogen storage tanks in the short term and advanced materials in the long term. (Some overlap with the Freedom Car project).
4- Increased funding in the area of infrastructure, and its technology verification
5- Increasing the hydrogen related research funded from the office of basic science in such areas as nanomaterials and membrane sciences.

However, progress in other areas has been slow. For example, the needed systems model to assess the evolution from near term technology to long term technologies is still being planned. Further more, the area of demonstrating low cost hydrogen production technologies has not been planned out, at a time when the price of gasoline has climbed to almost twice the levels at the NRC report was released.

Systems Analysis of US Energy Options

The development of a systems analysis model for the evolution of the entire energy program should have been far ahead by now. Instead, the program still relies on piecemeal analysis of each option, which often misses the links between various systems. The NRC called for the systems analysis effort "both to coordinate the multiple parallel efforts within the hydrogen program and to integrate the program within a balanced overall DOE national energy R and D effort. In particular to clarify the competition between electricity, liquid-fuel-based, and hydrogen based transportation."

The evolution of the technology advances in the alternative power trains for vehicles is such that it is very hard to pick an ultimate winner today. Progress is being made on batteries and on alternative liquid fuels, and both of these options has the potential to rely on domestic fuel sources, and to reduce the carbon emissions to the atmosphere. In addition, these two options can use the existing infrastructure. This a huge advantage vis a vis hydrogen, which requires a new infrastructure as well as a new technology for powering the car. The penetration rate of these two options could be such that they would satisfy the market well before the goals for the hydrogen fuel cell can be attained.

While it is possible to have hydrogen from carbon-free sources, it is also possible that it would be derived from a hydrocarbon source. Today, 95% of the hydrogen is made out of natural gas. If we take a somewhat optimistic scenario about growth of market share of hydrogen driven cars, our need for imported natural gas could be doubled by the year 2035, over what it would have been otherwise, and nearly four times what we import today. Today we import about 18% of our natural gas, a lot of which comes from Canada and Mexico. Future imports would rely more heavily on LNG, which would be much more expensive. Continuing to rely on natural gas for the production of hydrogen has its pitfalls in terms of energy security and environmental impact.

If the price of natural gas continues to rise, it will reach a point that the competing technologies of batteries and liquefied coal will be economically competitive with the hydrogen fuel cells. Such a comparison would be very useful to prioritize funding for the promising technology. The comparison should take into account the amount of funding that it would take to create the infrastructure for the distribution of each fuel.

Reexamination of Market Needs of Hydrogen

Almost half of the hydrogen produced in the US today is used at oil refineries for lightening the heavy oils to improve the products of vehicle and aircraft fuels. This use is

likely to grow as we extract heavier oils in the US and in Central and South America. With time the need will grow as even heavier oils are extracted from shale and tar, in the US and Canada. Given the size of the unconventional oil resources in North America (about 15,000 ExaJoules, as compared to 2,500 ExaJoules of conventional oil reserves in the Middle East), it is very likely that they would become a major source for our oil. In fact, Canada already produces aver a million barrel a day from tar sands, getting the needed heat from burning natural gas. The heat and hydrogen needed to sweeten the shale and tar-sand oil, could be produced from other sources such as renewable and nuclear sources, to avoid the carbon emission to the atmosphere.

Hydrogen production may become more important for the generation of liquid synthetic fuels before it becomes important for fuel cell vehicles. In particular a source of synthetic liquid fuel might become very attractive, which is the off gas carbon dioxide from coal fired electric power plants. If this gas is captured, and combined with hydrogen extracted from water by electrolysis or chemical means, it could become a source of alternative liquid fuel, such as methanol, ethanol or even gasoline and diesel fuels. Liquid fuels are ready, or easily adapted, for distribution using much of the established infrastructure. This will help solve the problem of imported oil, but it would only partially address the problem of carbon emissions, by eliminating or reducing emissions from fossil powered electric plants but not from vehicles. The technology is well known and has been demonstrated in Germany and New Zealand. The question is how economic is it now or in the future? The answer should be sought by DOE planners, with the aid of a systems analysis model. However, in a market with escalating prices of gasoline, and mounting desire to reduce carbon emissions, the answer is likely to be well before 2050

Hydrogen Production: The Case for Nuclear Energy

The technology for production of hydrogen on a large scale from fossil fuels is well established. The technology for distributed generation by electrolysis or small reformers, is available but could be improved. The technology to produce hydrogen from a non-emitting source, such as renewable or nuclear energy, is available but expensive. The application of electrolysis to produce hydrogen from hydro, wind, solar or nuclear energy would eliminate the emissions of CO_2 from the process. However, selling the product of electricity in the market is more financially rewarding than selling hydrogen.

Improving the cost of hydrogen production from electrolysis could come by using high temperature steam electrolysis using Solid Oxide Electrolysis Cells (SOEC), a process which has recently been demonstrated on a lab scale at Idaho National Laboratory. The electrolyzer cell energy efficiency of such a process was close to 90%, at a temperature of 850 C; this is a bit higher than the conventional electrolysis cell efficiency of 80%. However if the electricity and heat were provided by an advanced high temperature nuclear reactor, the overall efficiency could be 40% for the high temperature electrolysis, vs 35% for the low temperature electrolysis. Renewables as well as nuclear electricity can be used for either low temperature or high temperature electrolysis. However, for large scale and continuous production, to avoid the need for large storage facilities, hydro

and nuclear have an advantage over wind and solar. In addition, they would provide a lower cost options. Unfortunately, hydro power expansion potential is limited, but luckily, nuclear expansion is quite possible.

The production of hydrogen from nuclear is also possible using high temperature chemical reactions using heat alone (the so called thermochemical approach). At temperatures above 850 C, water splitting into hydrogen and oxygen become feasible with an energy efficiency over 40%. This possibility has been tested and shown to work in the US and Japan, on a small scale. In Japan, the process was coupled to a new type or nuclear reactor which allows reaching a very high temperature. This experiment was demonstrated on a small scale of 30 liters per hour last December. They are now moving ahead with a project for 30 cubic meters per hour, or 1000 times bigger. The project will be coupled to their 30 MW high temperature nuclear reactor that started operation in 2001. China also has a high temperature small reactor, and plans to couple it with hydrogen production are being made today.

In the US, we have no operating high temperature reactor. The DOE, as part of the international GEN IV program, selected this type of reactor as one of 6 concepts that would be useful as advanced reactors. It was designated as the first priority in the US GEN IV program, and plans to build a demonstration project in the future, named The Next Generation Nuclear Plant (NGNP), were initiated. However, it appears today that the program is retreating from the plan to build a demo plant, as the FY06 budget has no request for such an acquisition. It would be a mistake in my opinion to delay the testing of the technology needed to integrate a high temperature reactor with the hydrogen production technologies and be ready for commercial application by 2020.

The NGNP project relies in part on demonstrated technology, but needs certain developments before a plant is built:

1) Development of fuel manufacturing capability with a high quality control, starting with an oxide fuel but testing oxicarbide fuel on the way, and testing the irradiation effects on the fuel.
2) Development of a design for a heat exchanger capable of facilitating the interface between the nuclear and hydrogen islands
3) Development of helium turbo-machinery, as none has been built on a wide scale any where in the world. An alternative CO2 power cycle should be developed as well.

Thus, the above development could proceed in parallel with the design and licensing of a demo plant, and in the span of 5 to 7 years we could be ready to start construction of the plant. Assuming it could be built in three years and tested in various operational modes for five years, commercial viability and modifications could be ready in 15 years, i.e. By 2020. If the project is delayed, it would only delay the availability of this technology on a commercial scale.

The NRC committee assessed the potential future cost of production of hydrogen from various sources. The committee concluded that in 2003 the most economic means of hydrogen production was conventional Steam Methane Reformation or SMR (i.e. using natural gas), but that hydrogen production from electrolysis using modern Integrated Coal Gasification plants and high temperature nuclear reactors could very well compete with these means. Today, with the price of natural gas is much higher than in 2003, the economic comparison can only be better.

Furthermore, It is by no means certain that we will be able to sequester massive amounts of CO_2 from coal production of H -- and with any degree of certainty that they will stay sequestered. We also do not know what long term effects that would have on the sequestration reservoirs. Standards for sequestration have yet to be devised, and the debate about the ramifications has only begun. The issue mirrors the nuclear waste debate in the late 1960s, when everybody "knew" that the salt domes in Lyons, Kansas were the answer.

Even if some form of CO_2 sequestration were to work, an energy monoculture would not serve us well. We would be better served having both domestic sources nuclear and clean coal available to help fuel our transportation system in the future.

Mr. ISSA. Thank you and thank you for your insightful testimony when it came to areas that were slightly on the periphery of today, but absolutely within the jurisdiction of this subcommittee.

Dr. Sperling, I do apologize, we are going to be adjourning shortly after your testimony. I will try to get one or two questions in, but I am going to miss one vote, and that will be as much as I can miss.

Dr. Sperling.

STATEMENT OF DANIEL SPERLING

Mr. SPERLING. Thank you, Mr. Chairman. I will try to be brief. I do thank you for the opportunity to speak here on Federal policy toward hydrogen fuel cells.

I am a professor of engineering and environmental policy at the University of California, Davis. I direct the campus's Institute of Transportation Studies and co-direct our Hydrogen Pathways Research Program. I also served on that National Academy's committee that Dr. Kazimi just referred to, last year.

I am very pleased to provide testimony on this important subject. My statement is going to address the Federal portfolio of hydrogen research, development and demonstration activities.

I have one general recommendation and three more specific recommendations. First, though, I do want to note that DOE is doing, I believe, an excellent job of managing the hydrogen program in its Office of Energy Efficiency and Renewable Energy, especially given the constraints it operates under.

They are to be commended for their efforts to coordinate and to collaborate. They have developed strong relationships with the automotive industry. They have reached out to the oil industry, and they do seek outside input in developing their research programs and they also seek to coordinate with other Federal activities.

The principal challenges and concerns lie elsewhere. So my overarching recommendation and thought is that I do believe, as you mentioned earlier, the Federal Government needs to develop a strategic clean energy plan including, but not limited, to hydrogen. No such plan exists. A plan is needed that addresses how much money the Federal Government should spend on clean energy R&D relative to other priorities in science, technology demonstrations; what it should be spent on and who should receive the funding.

Congress needs to work with DOE, the National Science Foundation and others to develop this science and technology plan. This plan needs to articulate the priorities regarding how funding should be split between short and long term challenges; between fossil, nuclear and renewable energy; between science, technology and demonstrations; between industry, national labs and universities. It would be aimed at assuring that the United States continues to be a technology leader in the energy area, something very much at risk.

I have three more specific recommendations of what should be in that plan, what I would hope would be. First is a dramatic increase in fundamental R&D for clean energy production including hydrogen.

A clean energy revolution is about to get underway. Given the huge energy challenges and opportunities and given the huge public benefit that will result, one can only judge that current levels of Federal funding of energy R&D are far too low.

Note that the energy sector spends far less on R&D than most other sectors and that DOE spends far less on energy R&D than it did 20 years ago. Congress needs to rethink and expand the role of energy R&D. I note that the clean energy revolution is going to include some mix of renewable energy on the one hand and fossil energy coupled with carbon sequestration on the other.

The energy industries have great motivation to invest in carbon sequestration, and they are. But there is no analogous, well-funded stakeholder industry with a strong incentive to invest in renewable energy. Thus the most important role for the Federal Government is to accelerate the development of renewable technologies, including those that produce hydrogen.

Second, in my observation, my reading, the planned hydrogen demonstrations are probably about right in scale, but would benefit from a more targeted approach. Technology demonstrations are designed to meet a variety of goals, technology, political, educational, economic.

No single project can satisfy all these goals. Trying to do so almost always will result in failures. The challenge is to design small scale projects that each meet different needs. And yes, there is value in providing public exposure in different regions and beginning the process of educating fire marshals and the myriad of other local regulators.

But at this time the hydrogen demonstration projects should be small and directly tied to a goal. DOE needs to become more sophisticated about designing and evaluating these demonstration programs.

Third and last is I believe we need to dramatically expand clean energy funding for universities. Now, I know this sounds self-serving, but I believe it. If I don't say it, who will? Although I would hope some of my partners on the panel would agree, and I know they do.

Universities are the source of much of the breakthrough science in this country. Universities are also the place where scientists and engineers are trained. If energy research funding does not go to universities, universities are going to shift their attention elsewhere. Indeed that is what has happened.

In the past 20 years almost all the large energy centers and energy study programs at universities have disappeared. The thinning of energy research at universities is already undermining U.S. leadership in clean energy technology.

The United States will not be at the forefront of the coming clean energy revolution. It will not be able to respond effectively to energy security and climate change challenges without large new investments in university energy research.

Thank you.

[The prepared statement of Mr. Sperling follows:]

DANIEL SPERLING
PROFESSOR OF ENGINEERING AND ENVIRONMENTAL POLICY
DIRECTOR OF INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, DAVIS

TESTIMONY
BEFORE THE GOVERNMENT REFORM SUBCOMMITTEE ON ENERGY AND RESOURCES
UNITED STATES HOUSE OF REPRESENTATIVES

HEARING ON FEDERAL POLICY TOWARD HYDROGEN

JULY 27, 2005

Mr. Chairman and Members of the Committee, thank you for the opportunity to provide testimony on federal policy toward hydrogen and hydrogen fuel cell vehicle technologies.

I am a professor of engineering and environmental policy and director of the Institute of Transportation Studies at the University of California, Davis (ITS-Davis). I served on the 2004 National Academies committee to review hydrogen research at the U.S. Department of Energy. In December of 2002, ITS-Davis established the Hydrogen Pathways Research Program to address the very issues before your committee here today – to develop an understanding of the key technological, economic and market challenges associated with bringing hydrogen and hydrogen vehicle technologies to the market. This program receives financial support from nearly every major energy and automotive company in the world (17 in total), as well as from the U.S. DOE and U.S. Department of Transportation. Additionally, we are actively participating in other federal and state initiatives on hydrogen and fuel cell vehicle research, development, demonstration and public education. These initiatives include the U.S. DOE's *Hydrogen Fuel Cell and Infrastructure Technology* research program and *Controlled Hydrogen Fleet and Infrastructure Demonstration*, and the California Hydrogen Highway initiative announced by California Governor Arnold Schwarzenegger at our UC Davis hydrogen station in 2004. UC Davis is one of the world's leading university research centers for the study of advanced environmental vehicles and fuels including hybrids, fuel cells and hydrogen. We are happy to provide testimony on this very important subject.

My statement addresses the focus and balance of the federal portfolio of hydrogen energy research, development, and demonstration activities.

I believe that U.S. DOE management of the hydrogen program in its Office of Energy Efficiency and Renewable Energy (EERE) is not a concern. DOE is doing an excellent job in managing that program, given the constraints under which it operates. Indeed, the program managers are to be commended for developing strong relationships with the automotive industry, reaching out to the oil industry, seeking outside input in developing research programs and strategic plans, and coordinating with other federal activities. Larger issues and concerns are at stake and deserve our attention.

Non-Existent Research Policy

A primary concern is that there is no overall federal strategy to address the overarching question: How much money should be spent on clean energy R&D, for which technologies, and by whom? Without such an overarching plan or strategy, it is difficult to evaluate the funding of hydrogen research, development, and demonstration. I note that EERE is just one part of the federal hydrogen program. In the past, basic research was supposed to be the responsibility of the DOE Office of Science and the National Science Foundation. In response to the recommendation of the 2004 National Academies committee on hydrogen that more basic hydrogen research was needed, EERE began directing more funding at fundamental questions, as illustrated by the hydrogen storage Grand Challenge. I fully support that shift in focus (and elaborate below). The federal government, involving Congress and DOE (and perhaps others), needs to develop an integrated strategic plan for hydrogen and advanced vehicle research as part of an overall plan for clean energy research.

This strategic federal research plan on hydrogen and advanced environmental vehicle research would address the following questions. To my knowledge, they have not been addressed by the federal government, and only in passing by National Academies committees.

- How much should the federal government be spending on clean energy R&D, including hydrogen?
- How should those funds be split between basic science, technology development, and demonstrations?
- How should those funds be split between nuclear, renewables, fossil fuel, etc?
- How should funding for research be allocated among national labs, universities, and small and large companies in different industries?
- How should research be allocated among near term needs and riskier long term opportunities (across program areas and research organizations)?
- How can the hydrogen budget be insulated from the expanding practice of earmarking, which undermines effective program management?
- How is R&D funding best invested to maintain and enhance U.S. technology leadership internationally, with the goal of maintaining our strong economy?

Based on my reviews of various DOE programs and my own research, I have come to conclude that major changes are needed in the federal programs. I am certain that a strategic federal plan would come to the same conclusion.

Perhaps the most important change is a dramatic increase in basic research for renewable energy, and "clean" energy more broadly. A second desired change is to direct a larger share of this funding to universities, where the next generation of scientists and engineers are trained and where much of the breakthrough science occurs. Basic clean energy research can be a significant element in attracting and maintaining student interest in science, technology and engineering careers, as well as contributing to our global technical leadership.

The magnitude of federal funding of energy R&D is extraordinarily low given the energy challenges of the 21st Century and the huge public benefits resulting from energy investments. As David O'Reilly, CEO of Chevron, wrote in an open letter published in major periodicals earlier this month (July 2005),

> "Energy will be one of the defining issues of this century… The era of easy oil is over. What role will renewables and alternative energies play? What is the best way to protect our environment? How do we accelerate our conservation efforts? … We can not do this alone. Corporations, governments and every citizen of this planet must be part of the solution…"

With respect to R&D, what is the role of the federal government – Congress, DOE, NSF, and others – in this partnership? Clearly, Congress must take a stronger leadership role in articulating and formulating the broad outlines of a research portfolio. At present it involves itself in funding of particular programs, excessively so in the case of earmarking. But it does not step back and address the broader questions. A better prioritization and budget allocation process is needed to develop a broad plan to create an effective pipeline of science, technology and demonstration. It is difficult to make judgments about current federal energy activities because funding is dispersed across various programs and agencies. A few of us have some feel for how funding is allocated, but there is no mechanism nor document to guide us in making judgments about funding needs. Congress needs to address the questions listed above, and working with DOE and other agencies, it must develop a science and technology plan for clean energy, and hydrogen in particular.

Below is a summary of my suggestions and recommendations for federal actions to create an effective program capable of accelerating the transition to a clean energy system:

1. **Dramatically increase fundamental R&D, especially on clean energy production.** The hydrogen economy will depend on some mix of renewable energy, and fossil energy coupled with carbon sequestration. The energy industry has great motivation to invest in carbon sequestration, and is. But there is no analogous well-funded stakeholder industry with a strong incentive to invest in renewable production processes. Thus, the most important role for the federal government is to accelerate the development of renewable technologies. One large benefit to aggressively developing renewable energy is that improvements in these technologies can accrue to society regardless of when hydrogen is deployed. This is because many of the technologies can also be used for power production to supply energy to the electrical grid. The 2004 National Academies report emphasized the need for such fundamental research, recommending "targeted fundamental and exploratory research on hydrogen production by photobiological, photochemical, and thin-film solar processes."

This fundamental research would most logically be funded by the DOE Office of Science and NSF. The challenge is to determine where the opportunities lie, and where federal funding can most effectively accelerate innovation and benefit the public interest. For instance, funding for hybrid technology should be given low priority since the technology is already commercial and industry is already investing billions of dollars. Ideally, the more applied DOE offices of EERE and Fossil Energy would coordinate with

basic research initiatives elsewhere, and would provide strategic guidance to basic research in those other units.

2. Planned hydrogen demonstrations are about right in scale but would benefit from a more targeted approach. There are multiple goals for conducting technology demonstrations: technical, political, educational and economic. The temptation to satisfy all goals in a single project must be resisted. When all are targeted, the inevitable result is inefficient use of resources and reduced demonstration effectiveness. It should be kept in mind that most demonstrations don't become part of a commercialized stream of products nor an expanding fuel infrastructure. The demonstrated vehicles are obsolete the moment they are built, and most demo fuel stations are unlikely to be suited to a retail fuel system. The challenge then is to design small scale projects that each meet different needs. Yes, there is value in providing public exposure in different regions and beginning the process of educating fire marshals and the myriad local regulators. But at this time, they should be small and directly tied to a particular goal. In general, DOE should develop a greater sophistication about designing and evaluating demonstration programs – and communicating their strategy better to companies and taxpayers.

3. Dramatic expansion of clean energy funding for universities. Universities are the source of much of the breakthrough science, and train the scientists and engineers who will bring advanced technology into being. They also benefit society by encouraging an open sharing of knowledge, unlike industry researchers. The research conducted and the graduates who learn while doing this research will create the science and, in some cases, the technology basis for energy systems of the future. If energy research funding does not go to universities, the universities will shift their attention elsewhere. Indeed, that is what has happened. In the past 20 years, almost all the interdisciplinary energy centers at universities have disappeared. Almost all energy graduate education programs have been abandoned. The thinning of energy research at universities is undermining U.S. leadership in developing clean energy technology. Much increased energy funding of universities is needed to train the next generation of engineers and scientists, support innovation in the private sector, and maintain U.S. leadership in science and technology.

4. Better Congressional oversight. At present, Congress is too involved in managing programs and not involved enough in larger strategic issues. In particular, Congress needs to articulate priorities regarding the overall size of the energy research portfolio; the balance between short term and long term investments; balance between science, technology, and demonstrations; and funding mix between industry, national labs, and universities. DOE and NSF do not need Congressional review of particular programs. DOE and NSF already have a strong peer review process, make good use of the National Academies, and maintain many advisory committees that include industry and academics. Congress should instead focus on larger strategic questions.

5. Limit earmarking. The single most effective way to improve the productivity of DOE hydrogen programs would be to eliminate earmarking. Large swathes of the hydrogen budget have been earmarked the past two years. As the 2004 National Academies report on hydrogen and others have urged, Congress should restrain itself from earmarking science and technology funding.

Background on How UC Davis Is Contributing to the National Effort to Develop Hydrogen and Fuel Cell Technologies

I want to share with you the ways that UC Davis is making a difference in developing the technology, infrastructure and people to advance the state of the art of hydrogen for transportation. Due to the long transition time associated with vehicle turnover and fuel infrastructure introduction, business and policy decisions like those being considered here are being made today. These near-term decisions will affect the transportation and energy sector for many years to come. It is important that federal policy be shaped by the best available current knowledge and that future policy be shaped by objective research.

Brief Descriptions of Related ITS-Davis Research

About 35 graduate students and ten faculty members are involved in advanced environmental vehicle and fuels research on the UC Davis campus. Graduates of our interdisciplinary Transportation Technology and Policy (TTP) program have obtained positions within the automotive and energy industries, academia, environmental NGOs, and government. The following is a sampling of our larger programs:

Hydrogen Pathways Research Program
The Hydrogen Pathways Research Program is a multi-year program designed to look at the near to mid-term introduction of hydrogen as a transportation fuel from a technical, economic, market, and policy perspective. Bringing together people already working on these issues, the ITS-Davis Hydrogen Pathways Research Program has engaged a broad consortium of 21 leading energy and automotive companies and government agencies, including Air Products, BP, California DOT, Chevron, ConocoPhillips, ExxonMobil, General Motors, Honda, Indian Oil Corporation, Natural Resources Canada, Nissan, PG&E, Petrobras, Southern California Gas, Shell, Subaru, Total, Toyota, U.S. EPA, and the U.S. Department of Energy and U.S. Department of Transportation .

Fuel Cell APUs: A $3 million project is developing and testing fuel cell auxiliary power units (APUs) that power truck-trailer refrigeration and other auxiliary systems. The new APUs could eliminate the need for idling big-rig diesel engines, which is inefficient, expensive, noisy, and polluting. Fuel cell APUs could also power electric systems in aircraft, leading to fuel savings in the nation's future commercial aircraft fleet.

Advanced Vehicle Modeling: ITS-Davis researchers conduct extensive computer modeling of vehicle and heavy-duty truck emissions, fuel economy and performance. ITS-Davis recently completed a five-year, $3 million fuel cell vehicle modeling program that was sponsored by 20 companies and three government agencies.

Hybrid Vehicle Prototypes and Component Evaluations: The UC Davis Hybrid Vehicle (HEV) Driveline Research and Design Center designs and builds vehicles that demonstrate improved overall efficiency, high fuel economy and low emissions. The HEV Center's current efforts focus on plug-in hybrid-electric vehicles (HEVs) and continuously variable transmissions (CVTs). Researchers at ITS-Davis study energy storage and

conversion technologies (including ultracapacitors) for electric, hybrid-electric and fuel cell vehicle applications for a variety of government and industry sponsors.

New Advanced Environmental Vehicle Laboratories: The UC Davis College of Engineering and ITS-Davis are planning to build a new advanced environmental vehicle facility. This project would create large synergies by clustering UC Davis clean-vehicle research and education programs. The facility would include high-bay vehicle laboratory space, a distributed computing facility and a hydrogen refueling station. Co-funding from public and private sources is currently being sought.

Graduate Education

We are especially proud of the success of our expanding graduate education and research program much of which involved advanced fuels such as hydrogen and advanced electric-drive vehicles. The National Science Foundation awarded ITS-Davis a $2.6 million Integrative Graduate Education and Research Traineeship (IGERT) grant for our innovative Transportation Technology and Policy graduate program, the only transportation institute in the country to be funded. In addition, the U.S. Department of Energy awarded UC Davis two (of ten nationally) Graduate Automotive Technology Education (GATE) Centers – to ITS-Davis for fuel cell vehicles and to the Department of Mechanical and Aeronautical Engineering for hybrid electric vehicles. UC Davis won the first two (1998 and 2001) FutureCar and FutureTruck competitions sponsored by the U.S. Department of Energy and the USCAR program of the U.S. auto makers, and placed second overall in the 2003 FutureTruck competition.

Selected ITS-Davis Publications:

Daniel Sperling and James S. Cannon, *The Hydrogen Energy Transition: Moving Toward the Post-Petroleum Age in Transportation.* (Elsevier, 2004).

Daniel Sperling and Joan Ogden, *The Hope For Hydrogen*, Issues in Science and Technology. (Washington, D.C.: National Science Foundation, April 2004). (ITS-Davis Research Report UCD-ITS-RP-04-19 http://www.its.ucdavis.edu/pubs/pub2004.htm.

Lipman, Timothy, D. Kammen, D. Sperling, and J. Ogden, "An Integrated Hydrogen Strategy for California," Report to the Kirsch Foundation, *ITS-Davis,* RR-ITS-RR-04-43, August 2004. http://www.its.ucdavis.edu/publications/2004/UCD-ITS-RR-04-43.pdf

The ITS-Davis reports and articles, along with additional information on our programs are available at www.its.ucdavis.edu AND http://hydrogen.its.ucdavis.edu.

Mr. ISSA. Thank you, and you did just about as good a job of explaining that as Dr. Rountree did from the University of California at Berkeley a couple of weeks earlier.

You are right. That's why in this subcommittee it does seem as though the University of California makes that point at every hearing.

Probably the biggest question I can ask of the private sector here today, and it is for everyone, but to be honest, Dr. Burns, it is going to fall squarely in your lap, when is your best estimate of when the consumer would be able to buy a hydrogen automobile without all the frills, but the basic automobile, if you will, in the $30,000 range, plus or minus.

Mr. BURNS. My best estimate would be in the 2015 to 2020 timeframe.

Mr. ISSA. In 2015.

Mr. BURNS. The 2015 to 2020 timeframe.

Mr. ISSA. Is there anyone who thinks that range of 2015 to 2020 is unreasonable?

Let me just followup with one additional question, as somebody who has had three hybrid automobiles and has a fourth on order, and who notices the parking lot of Congress is practically a used car lot of hybrids at this point, when would you offer the automobile that is 25 to 30 percent more expensive than its counterparts but that appeals to early adopters—and included in that I believe should be the Federal Government.

When would that occur?

Mr. BURNS. Well, we certainly think we can have the propulsion system designed and validated by 2010. So, I would put that in that 2010 to 2015 window. It is going to depend in part on the availability of the hydrogen. I think Dennis referred to this as the chicken and egg dilemma.

We don't want to put our capital into a capacity to build cars if hydrogen isn't conveniently and safely available to our customers. We certainly can understand why the energy industry wouldn't want to put significant capital into fueling stations if the vehicles aren't available.

That is really the transformation that needs to be managed. First you have to get the technology right and proven and it has to be cost competitive.

Mr. ISSA. A question I don't know the answer to at all: what is the cost of the smallest, least expensive, micro-producer of hydrogen? Can I buy a hydrogen producer that I hook up to my natural gas line and produce hydrogen at home to refuel my automobile at a competitive price?

Mr. BURNS. Well, certainly there are a number of companies with the vision to do just that. That is the beauty of hydrogen. It is as widely distributed today as the water and natural gas needed to make it. Most all of our homes and businesses have it.

We like to think of the infrastructure challenges as an appliance issue as opposed to pipelines and refinery and ports and other things. So, the real question is can you get an appliance that either uses the sun, uses electricity from other sources, or reforms natural gas at your home that can create hydrogen at a competitive price to petroleum.

Mr. ISSA. No, that was my question. I wanted your answer.

Mr. BURNS. My answer is I absolutely believe that can happen. I believe that can happen in the 2015 timeframe. I have seen studies of companies that claim that is possible.

Mr. ISSA. I was hoping for an earlier date. You will notice that.

Mr. KAZIMI. As of today, I think if you are trying to get an electrolyzer that gives you substantial quantities, you are talking about $50,000 and above. So, it is not yet available for the average household.

Mr. BURNS. Let me just make it clear, as we reach our target of $50 per kilowatt for our fuel cell propulsion system, which is our 2010 target, electrolyzers are fuel cells running backward. So they are basically the same technology. They run at higher pressure.

So, we believe the enablers that will allow us to get fuel cells cost competitive will do similarly for electrolyzers——

Mr. ISSA. Dr. Sperling.

Mr. SPERLING. Well, you know, the bigger issue is that hydrogen, as Dr. Burns said earlier, there is a lot of hydrogen being produced. It is produced at a cost of probably under $2 a gallon equivalent.

So, especially from fossil sources we can make it. We need to develop ways of sequestering carbon when we make it using fossil sources. But it requires in that case a large distribution system to efficiently move it from a source where it can be produced fairly efficiently to the end users.

What Dr. Burns is talking about is that until that kind of distribution system is set up, perhaps a better way to do it is, and perhaps go in parallel with it, is developing very small units that can be at the household or local neighborhood level.

You know, this is part of this challenge of the transition, how do we get from here to there? How do we get started?

It is not obvious. It is not straightforward. Parts of it need a lot of research.

Mr. ISSA. I am in the business of pushing hard to try to get that for people who can produce it. But I will ask each of you, to the extent that you have resources, to make this committee aware in the following days or weeks or even months, if you remember us, if you discover anyone who is, if you will, on that track already because I know that my house has natural gas, I know my house has water.

To be candid, if a micro-unit were available today, I think there would be lots of early adapters who would be saying, it could be $100 a kilowatt and I am still willing to do it, particularly if I have a solar cell in the back or something else where I want to be zero emissions.

Let me get to the heart of one of my concerns, though, since I have to answer this bell.

There has been a lot of concern—and I know Dr. Burns and Mr. Campbell, you have it, too—about providing data that could be further shared from industry that might in fact, as often is claimed in Europe, could be shared with competing companies.

Do you feel that the Federal Government has put in the safeguards and if not, what would you suggest that we do to make sure that you are able to fully provide us with the kinds of information that you cannot risk letting a competitor have?

Is that firewall in place and if not, can we do more to make it be in place so that we can have the kind of data that would allow these programs to go forward a lot faster?

Mr. CAMPBELL. Well, I think we can do more to provide data on the actual progress in terms of where we are. We have been much more open this year at Ballard than we ever have been in the past.

We felt there was a lot of misinformation out in the marketplace about the state-of-the-art with respect to the technology. So, we kind of opened our kimono and are sharing our cost levels and where we are in durability. This is information that in the past we kept private. We think it is important to get that news out there so people can really see how far the technology has advanced.

You do have to protect your intellectual property, but I think there is a great spirit of collaboration in this industry today where automakers are collaborating, technology companies are collaborating. There is a realization that by working together we can move this thing a lot faster.

Mr. ISSA. Thank you.

Mr. BURNS. Mr. Chairman, I appreciate your sensitivity on that issue. We worked very hard with the Department of Energy on their hydrogen fuel initiative on that exact issue. It did take a little longer than both parties expected to reach agreement on protecting the privacy of the data, but we feel we have reached a good common ground on that and we appreciate DOE's sensitivity.

I just want to emphasize, it is a very important issue. The fundamental reason why General Motors is pursuing this as aggressively as we are pursuing it is we see a tremendous business growth opportunity here. We see an opportunity to take the world's auto ownership from beyond just 12 percent of the world's population.

We see a vehicle that is simpler, that is more exciting to own and drive, that emits just water, that can get from renewable energies and provides a foundation for a dramatic growth of our industry.

We want to have a competitive advantage as we pursue that, so I appreciate your sensitivity on that. I believe we can work through the issues as necessary.

Mr. ISSA. Thank you. I would like to thank all the panelists here today.

In closing, the path to realizing the hydrogen economy has been described as a moon shot, or an Apollo shot to paraphrase the statement made here today, by some skeptics—fraught with technical and economic challenges. But the importance of getting the economy away from its dependence on foreign oil in an environmentally responsible manner justifies such an ambitious initiative. We are halfway through the President's 5 year hydrogen initiative and as today's hearing indicates, we have already begun to see results.

Moreover, Congress is just hours from passing the most comprehensive clean energy bill in this country's history. This bill will be a further step in moving expressly toward a hydrogen economy.

At the same time, our witnesses noted that the Federal investment must be on a par with these challenges, dramatically greater. The investment must be dedicated in a strategic way and it must be accountable for the dollars spent. That is why congressional

oversight hearings like this are so important and why this one is so timely.

I am personally a fan of the goals of Kyoto. Although we never affirmed it here in the House or in the Senate, the only way we get to Kyoto is through, among other things, the President's vision for renewables, for nuclear and for hydrogen.

If there is anything that both sides of the aisle should be committed to, it is reaching those three goals.

On that I will hold the record open, contrary to an earlier statement, for 2 weeks from this date so that you may put forward any additional submissions.

Beyond that the committee, though, will accept your submissions, not as part of the record, but for our continued work, at any time.

With that, this meeting is adjourned with my thanks.

[Whereupon, at 2:35 p.m., the hearing was adjourned.]

[The prepared statement of Hon. Diane E. Watson follows:]

Opening Statement
Congresswoman Diane E. Watson
Government Reform Subcommittee – Energy and Resources
Hearing: The Hydrogen Economy: Is it Attainable? When?
July 27, 2005

Thank you Mr. Chairman.

The global thirst for oil has placed the United States in a precarious position. American consumers are caught in the squeeze of unregulated gas pricing. Commuting by car is a necessity in Southern California, and record gasoline prices are taking their toll on my constituents. Americans across the country are very concerned. A hydrogen economy sounds like a wonderful solution, but my concern is, "What is the science and reality behind such an initiative?"

It has been mentioned that the vision of the hydrogen economy rests on two pillars: a pollution-free method for producing the hydrogen itself, and a cost effective means for efficiently converting the hydrogen into useful energy without generating pollution. Unfortunately, hydrogen does not exist in

nature in its pure form. Therefore, hydrogen must be collected by separation from other chemical compounds. The most common methods include extraction from water by electrolysis, extraction from hydrocarbon fuels by thermal cracking, or extraction from any other hydrogen carrier by chemical processes. The energy type used to initiate the extraction processes is directly proportional to the environmental benefit that hydrogen can produce. In other words, if you must use natural gas or coal to extract the hydrogen – we are still polluting the atmosphere.

Mr. Chairman, the Presidents hydrogen initiative is a commendable thought, but my constituents want to know if there is a commitment, backed by science, behind that thought. Several states, including California, have initially bought in to the President's hydrogen initiative. The Governor of California insists that his proactive approach with hydrogen is a remedy to poor air quality and also a platform for a robust economy in California. Governor Schwarzenegger's "Hydrogen Highway" proposal envisions hundreds of hydrogen fueling stations across the state. These stations will be used by thousands of hydrogen-powered cars and trucks and buses. It is my duty to question if California taxpayer money is being spent wisely.

Hydrogen use may be a long-term energy solution, but the National Academy of Sciences concludes that the hydrogen initiative has difficult technological and economic challenges to overcome. The in-depth report on the feasibility of a hydrogen economy titled, *The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs (March 2004),* further states that concerns about cost, environmental impact, and safety need to be addressed.

The cost of extracting hydrogen from water is higher than extraction costs from natural gas or coal. One report places the pricing at $5.6 per gigajoule (gig-a-jewel) to produce hydrogen from natural gas, $10.3 per gigajoule to produce hydrogen from coal, and $20.1 per gigajoule to produce hydrogen through electrolysis (from water). Similar to the energy released when burning a million wooden matches, a gigajoule of gas will cook over 2500 hamburgers, and a gigajoule of electricity will keep a 60-watt bulb continuously lit for six months. Making hydrogen from water by electrolysis is the most expensive and energy-intensive way to produce the fuel. Conversely, it is the most environmentally clean process.

Environmentally, hydrogen itself does not produce any harmful by-products. The only emission is pure water. Therefore, it could help reduce air pollution problems such as smog, particulate matter, and green house gasses. Today, the United States is responsible for about one-fourth of the world's total emissions of carbon dioxide. New technology must produce another cost effective way to convert hydrogen into an energy source without generating pollution.

Safety concerns are directed at the flammable and explosive nature of hydrogen gas. Not only must the vehicles that use the hydrogen fuel be brought up to acceptable safety specifications, but the transportation system for the hydrogen and the filling stations for the hydrogen must be just as safe for the general public.

Mr. Chairman, I want to commend you again on this hearing. American citizens need answers. It is critical that we counteract the reason for high prices at the gas pumps and develop any environmentally sound energy alternative that we can. It is imperative for our economy and for the independence of our great nation. I look forward to this informational session with the U.S. Department of Energy, The Office of Science and Technology Policy, the

California Energy Commission, as well as representatives from academia and industry. I yield back.

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